Modelling winning performance in invasive team games

Thesis

UNRESTRICTED

Modelling winning performance in invasive team games

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Declaration

I hereby declare that the substance of this thesis has not been submitted, nor is being concurrently submitted, in candidature for any other degree.

I also declare that the work embodied in this thesis is the result of my own independent investigation. Where the work of others has been used, this has been fully acknowledged in the text.

Dr. Keith Lyons
(Director of Studies)

Abstract

This study reports a four-year investigation into winning performance in invasive team games. The aims of the study were: to identify patterns of winning performance in two invasive team games (Aim 1); and to propose a generic model of winning performance in these games (Aim 2). Four research questions were derived from these aims: Can data gathered by real-time notation systems be used to develop a model for coaches and performers of winning performance?; Do winning teams in rugby union or association football exhibit any observable patterns of behaviour?; Is it possible to profile performances of winning teams in invasive games as an 'ideal type'?; Is it possible to construct a predictive model of winning performance in invasive team games?

Data were collected by real-time hand and computer notation systems from 105 international fixtures (52 rugby union games and 53 association football games). The systems used underwent rigorous validity and reliability checks and were found to be valid and reliable research instruments.

Data from the two sports were subjected to thirty investigations (16 for rugby union and 14 for association football) in order to identify patterns of winning behaviour. This behaviour was then presented as an ideal type model of winning in rugby union and association football. Whilst it was acknowledged that within-game and within-sport differences rendered the modelling of performance difficult, it was proposed that some extraneous factors, some key performance areas and some scoring

characteristics could be combined to provide an ideal type of winning. A limited, generic model of winning in an invasive game was also proposed.

It is concluded that an ideal type model sensitive to quantitative and qualitative data can be constructed for winning performance. It is noted that the spirit of ideal type modelling is sensitive to the dynamic interplay of structural components of games playing and individual action and virtuosity.

Directions for future research are identified.

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Author Note

This research was undertaken as a Research Assistant at the Centre for Notational Analysis (CNA) at the University of Wales Institute, Cardiff (UWIC). The research was carried out over a period of four years. The proposal was submitted during September, 1993 and final submission of the thesis was in December, 1997.

The research was made possible with the financial assistance of the Faculty of Education and Sport at UWIC. Special thanks must be given to those involved in assisting with and supervising the study: Dr. Keith Lyons (Director of Studies); Dr. Mike Hughes (Second Supervisor); Professor Alan Birchenough (Second Supervisor); and to the other members of the CNA who assisted in a variety of ways with the study.

At the time of registration for a higher degree, the researcher was already a worker in the CNA with responsibility for data gathering for a governing body of sport: the Welsh Rugby Union (WRU). Central to this work was the provision of augmented information for coaches of international teams immediately post-event. The idea for the research stemmed from an undergraduate dissertation written by the researcher as part of the requirements for a BA degree while studying at UWIC (then South Glamorgan Institute of Higher Education) from 1987 -1990, and followed on from consultancy work with sports governing bodies and associated clubs in the years that immediately preceded this research. The four year period of study proved a personal challenge to use notational analysis as a means of offering some explanation as to the pattern of behaviour of winning sides within invasive team games. For research to be fully complete its findings should be shared with others. It is hoped that this study will prove worthwhile not only to notational analysts and sports scientists but also to those more directly involved with invasive team games. Notational analysts have long held that their involvement should always complement the coach's needs and the overall aim of this research was always to be able to offer information to coaches and players that would help maximise their efforts.

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I had six honest serving men
They taught me all I knew
Their names were Where and What and When
And Why and How and Who.

Rudyard Kipling

Chapter One: Introduction

1.1 Introduction

This study addresses fundamental and applied sport science issues in the analysis of performance. In the 1980s in the United Kingdom, a small group of researchers, located mainly in emerging sports science departments in polytechnics, established an agenda for research in notational analysis that identified description, modelling and prediction as important outcomes of empirical investigation (Brackenridge and Alderson, 1985; Alderson et alia,1990).

In the intervening years, some sports scientists have pursued fundamental aspects of research (Franks and McGarry, 1996) whilst others have pursued applied work with governing bodies of sport, coaches and performers. Franks and his colleagues at the University of British Columbia have been particularly successful at combining both aspects of research and have established a tradition of peer review publications for their work. The Centre for Notational Analysis at the University of Wales Institute Cardiff has also attempted to combine fundamental and applied research.

This investigation is intended to be a significant contribution to research into the analysis of performance. The empirical focus for the study is a category of games that taxonomists characterise as 'invasive team games' (see, for example, Read and Edwards, 1992). To date much of the work in notational analysis has used time and motion approaches to describe performance in sport. Little attention has been paid to the comparative dimensions of this work and to the modelling issues that might arise to optimise performance. This epistemological gap stimulated the researcher to investigate whether a model could be developed that could be used to develop performance and predict a pattern of winning play.

Patrick and McKenna (1988) argued that the "simple summation of match statistics" could not be used as a reliable indicator of a successful team and they believed that there were a number of other variables which interacted to affect a game's outcome. This study posits that winning teams do manifest differences from losing teams and discusses those variables that appear to influence the final score. The challenge has been to identify the theoretical and empirical warrant for these differences.

The aims of the study were: to identify patterns of winning performance in two invasive team games (Aim 1); and to propose a generic model of winning performance in these games (Aim 2). Empirical data were collected in real-time (in-event) with hand and computer notation systems during international rugby union and association football fixtures. The development of a model based on data collected in real-time was identified as an important condition of the study. The study reported here emerged from this back-cloth.

1.2 Formulating the title of the study

The initial title of the research proposal was *Modelling Successful Performance in Invasive Team Games*. The researcher's intention from the outset had been to examine invasive team games, particularly rugby union football and association football, and then to develop a model for the patterns of these games and to examine whether there was a generic model of performance that could be established through data analysis within these two sports that could then be applied to other invasive team games.

In discussions about the conceptual and empirical focus of the study with a focus group of sports scientists, coaches, players and administrators, questions were raised about the use of the word 'successful' in the title of the study. Coaches, for example, attached importance to knowing the pattern of the team that won a tournament that they entered whether it was the Rugby Union World Cup, the Five Nations' Rugby Union Championship, the Soccer World Cup, or the European Soccer Championship. All of the coaches in the focus group for this research assumed that teams that win tournaments are successful teams. Sports scientists encouraged me to think carefully about how the term 'successful' was to be operationalised.

All formalised invasive team games have a set of 'objective' rules or laws. These specify the mode of play and define how a final result is obtained. In rugby union football and association football the outcome can be win, draw or lose. In this respect, in absolute terms, the winner is the successful team since it has achieved the end state of the contest according to the rules or laws. However, some teams aim to achieve identified performance goals within a particular game independent of winning or losing. In this respect a team can have a relatively successful outcome without it necessarily being an absolute winning outcome.

Most teams are likely to have a combination of goals. In the 1991 Rugby World Cup, for example, Western Samoa were competing in the final stages of that competition for the first time. They set themselves the goal of reaching the knock-out stages (the final eight teams) in order to automatically qualify for the subsequent tournament in South Africa in 1995. In their case, although they wanted to win every match they played, they were aware that two victories out of three pool games would enable them to achieve their goal.

Keating (1963) categorised games playing according to a "product emphasis ranking" (end result) and a "process emphasis ranking" (equal concern with the quality of the performance and the outcome).

Table 1: Categorisation of Games Playing (Keating, 1963)

Rank	Product Emphasis Ranking	Process Emphasis Ranking
1	Winning and playing well	Winning and playing well
2	Winning and playing poorly	Losing and playing well
3	Losing and playing well	Winning and playing poorly
4	Losing and playing poorly	Losing and playing poorly

For the purpose of the study it was decided to operationally define the score-line at the end of a game as **the** prime, objective performance indicator of successful play. The title of the study submitted to the Open University thus became *Modelling **Winning** Performance in Invasive Team Games*.

1.3 Winning: Does the better team always win?

Notwithstanding the operational definition of winning performance identified above there remain some important conceptual issues about winning performance from a modelling approach. One important question is whether the team that wins is always the 'better' team. Are there any extraneous influences, for example, which lead to a 'better' team losing?

Burwitz et alia (1992), for example, call for a broad perspective to be taken when analysing performance:

> Sport does not take place in a vacuum and, as such, research needs to take into account of the complex interactions between the mechanical and physiological, cognition and emotion, the historical and environmental context, social groupings, political and economic factors and ideological and philosophical issues.

It was important in the framing of the research study to decide whether these extraneous influences were to play a role in the modelling of winning performance or whether they were to be regarded as independent of the modelling process. The literature suggests that some of these extraneous influences may have an impact on winning performance. Two of these influences are match officials and home-ground advantage, and they are considered within the discussion of data in Chapter Four.

1.3.1 Match officials

All formalised invasive games have rules or laws that are refereed or umpired by an 'impartial' official. Dunning and Sheard (1975), amongst others, have indicated the nineteenth century origins of rugby union football and association football and the role referees played in the emergence of distinctive codes of football. In late twentieth century sport, governing bodies have well-established training and development programmes for referees and umpires. In rugby union football and association football, all international fixtures are now refereed by a person from a neutral, third, country. Thomas (1995) has undertaken original and thought-provoking research into refereeing behaviour in international rugby union football.

1.3.2 Home-ground advantage

In the United States of America, sports' lore has long held that a team playing on its home ground has an advantage over its opponent, that is, that the home team wins over 50% of their games. Edwards (1979), for example, examined the results of 349 professional and 577 college American football games in the two seasons 1974-75 and 1975-76. Of the professional games 54.4% (190) were won by the home side and the pattern of points scored indicated that home teams enjoyed a three points advantage. In the college games 58.6% (338) were won by the home side with a margin of victory of more than five points. These figures replicated work by Schwartz and Barsky (1977), Lane (1976) and Altman (1975) where home teams were reported to be more likely winners (particularly in the case of college matches). In summary, home teams won between 55% and 60% of all matches by approximately the score of one touchdown and the advantage was reflected in various offensive statistics such as first downs, completions, rushing and passing yardages.

Edwards (1979) also examined the results of four professional baseball teams in the 1975 season. Two teams from each of the National and American Leagues were identified with one from each having an overall winning and overall losing record. Of 288 home games played, 160 or 55.6% were won by the home team. There was a slight home-ground advantage but this was not reflected in average runs or winning margins. A study of playing records in conjunction with home-ground advantage indicated that a team's record was more important than home field advantage. Snider, cited in Edwards (1979) stated that:

> In evaluating pro basketball, the home court is the big factor. Home teams have a 71% rate for success ... Figure the home court to be worth 3 to 7 points depending on the team and the floor.

In the 1976 season none of the NBA teams had a winning 'road' record while the teams that made the playoffs won over 85% of their home games. The Chicago Bulls shooting percentage for field goals and free throws was 10% higher at home. Altman (1975) reported that the University of Utah won two-thirds of its home games over a three-year period but won only a quarter of its away games.

Academic interest in research into home-ground advantage abated somewhat after this incandescence of American studies but Courneya and Carron (1992) reviewed the literature on game location and its influence on the end result and identified a total of 19 studies in four invasive team games (American Football, Ice Hockey, Basketball, and Soccer) between 1977 and 1992 which discovered that the home team won between 57% and 69% of their games. They concluded that home advantage did exist in major team sports and the magnitude of this advantage, despite remaining stable within each sport over time, did vary among sports. It is proposed to make a contribution to this issue in Chapter Four.

1.4 Research questions

The aims of the study presented in **1.1** framed the research questions that became the focus for the theoretical and empirical investigations reported in this thesis. Four questions were identified. These questions and the rationales for their use in the study are discussed here.

1.4.1 Question one: data-driven models of winning performance

Can data gathered by real-time notation systems be used to develop a model of winning performance for use by coaches and performers?

Focus group discussions (see **1.2**) generated a range of concerns about the role of real-time analysis and whether there were robust indicators of winning performance. It was important, therefore, to identify whether there were valid and reliable real-time hand and computerised notation systems that could be used for rugby union and association football. More (1994) has presented a detailed account of the opportunities offered by data-driven intervention studies with association football coaches. Question one thus appeared an important starting point for the study and a contribution to a cumulative tradition of research.

1.4.2 Question two: patterns of winning performance

Do winning teams in rugby union or association football exhibit any observable patterns of behaviour which differ from losing teams?

Work undertaken by the researcher (Potter 1990, 1995) had suggested that winning teams had a metaphorical handprint of observable behaviour that distinguished them from losing teams. This earlier work stimulated the second research question. It was conjectured that systematic observation of performance in the two chosen invasive games would: provide a database for the study; form the empirical evidence for first order ('factual') and second order ('conceptual') questions about winning performance. It was anticipated that the provisional answers to these first and second order questions would encourage a developmental approach to the study and open up further related questions. Are there any apparent extraneous influences on winning? Do winners score first? Do some countries have a habit of winning (and losing)? Do winners establish rhythms of performance that facilitate winning outcomes? Does winning happen by accident or design? It was hoped that such a research question and related questions would enable careful scrutiny of the structures of games and their situational components.

1.4.3 Question three: an 'ideal type' of performance

Is it possible to profile performances of winning teams in invasive games as an 'ideal type'?

Question three was identified to further develop the conceptual trend inherent in question two. The writings of the German sociologist Max Weber (1947) prompted this third question. He suggested that the 'ideal type' must be both 'objectively possible' and 'subjectively adequate'. In order to address Aim 2 of the study ('to create a generic model of winning performance') it seemed imperative to discover whether there could be a profile of the performances of winning teams in invasive games that would meet some of the characteristics of the Weberian ideal type. The invitational mode of 'ideal type' investigations was particularly attractive.

1.4.4 Question four: prediction

Is it possible to construct a predictive model of winning performance in invasive team games?

The fourth question was formulated to address an epistemological legacy from the origins of notational analysis. In the United Kingdom in the 1980s a range of sports scientists sought to link the trinity of description, modelling and prediction. The agenda for notational analysis in the late 1990s was set at that time (see, for example, Alderson et alia, 1990). Given that these pioneers used some of the first generation microcomputers and still sought the prediction touchstone, could it be possible to use the formidable computational resources of present-day powerful microcomputers to interrogate relational databases to predict performance? Could a chaotic, catastrophic, probabilistic, statistical or rhythmic model exist within winning sporting performance? Could data collected be filtered through different model systems and evaluated to enable the researcher to discover whether there are any generic performance indicators that exist within invasive team games?

1.5 Limitations of the study

There are a number of limitations of the study. The single most important limitation is the technical equipment used by the researcher. During the four years of the study there has been a phenomenal growth in the quality and cost of video and computer technology. The study would have undoubtedly taken a different approach to data capturing and analysis if it was to be started in 1997. As it was, research funds were provided to purchase the best touch screen laptop computer available in 1994. But during the research there was a serious hard-disk error on this computer. Not only did this cause a long delay in data capture and the writing-up process, it also meant that some work had to be repeated.

The acquisition of a complete off-air broadcast video archive for the research took some considerable time. Delays in receiving video material slowed down the progress of the data collection. Even with the archive, a recurring limitation of broadcast material was the loss of action due to slow-motion replays, alternate camera angles or technical breakdowns. The protocol used in the research was to make logical assumptions as to the action that was lost and since these periods were usually very brief, the accuracy of the data collection was not adversely affected. The database is thus not complete but as complete as possible under the circumstances.

Four of the five tournaments that were used for the study took place within the first two years of the research study but the association football European Championship was not held until the summer of 1996. It was important to use this tournament as one of the data sets since it provided a worthwhile comparative analysis with the Five Nations rugby union data sets.

In summary, there are a number of limitations of the study. Throughout the research the supervisory team provided advice and support. Research appears to be a potentially messy process and part of the apprenticeship of higher degree work is to learn how to adapt to unexpected problems that some books on 'How to be a PhD' ignore. Throughout the thesis the researcher has attempted to be open about such problems and not to confine them solely to this paragraph.

1.6 Delimitations of the study

When first conceived the research aspired to focus on winning performance in four invasive team games. It became very apparent early on in the research that four games were too many. The depth of analysis required and the amount of time needed to produce valid and reliable data in pilot studies necessitated a strategic and pragmatic decision about which games to include and which to exclude. With considerable reluctance it was decided to exclude two women's games: hockey and lacrosse. The researcher had worked closely with the men's variants of rugby union and association football and although there was a strong tradition within the Centre for Notational Analysis of working with women's hockey and lacrosse the researcher had limited practical experience of either game. In this respect the research has a gender specific focus. However, since that decision was taken three other research projects have been initiated within the Centre for Notational Analysis that focus on women's hockey and lacrosse. That work has provided an important backcloth to this study and a source of on-going discussion.

The study was further delimited to real-time notational analysis and to a finite sample of matches within the two chosen sports. It was decided to investigate tournaments, that is, World Cups and European Championships rather than individual international fixtures. Such tournaments provide opportunities for intensive data capture and are normally covered in their entirety by broadcast television. Three rugby union tournaments were observed: 1995 Five Nations' Championship; 1995 Rugby World Cup; and 1996 Five Nations' Championship. Two association football tournaments were observed: 1994 FIFA World Cup; 1996 European Championship.

The decision to delimit the study to examine those variables that could be collected during real-time did constrain the detail that could be collected. Hand and computerised notation systems were used.

1.7 Definition of terms

As with any research study, terms are used here which are common within the discipline but may be unfamiliar to others. There are two separate groupings of terms within the study which need to be defined. Firstly, the more general language used within the field of notational analysis and secondly the more specific terms linked with rugby union and association football that are used within the computer software and analysis sections of this thesis.

1.7.1 General terms

1. Invasive Team Game:

In a taxonomy of game playing, an invasive game is characterised by a rule structure that requires a team to score by entering (invading) an opposing team's territory. Invasive games can be played on a court (for example, basketball and netball), a field (for example, association football and rugby union) or a rink (for example, ice hockey). Modes of scoring vary and can involve baskets, goals and tries.

2. Real-time analysis:

This is sometimes referred to as in-event analysis. Both terms indicate that data are collected simultaneously with the live match, or live from televised broadcasts, or as if live from video recordings. Data are collected for the whole game.

3. Lapsed-time analysis:

This is sometimes referred to as post-event analysis. Both terms indicate that data are collected from video recordings using frame-by-frame analysis. The video can be rewound and replayed as many times as necessary. Such analysis can take place over an extended period of time in substantial detail.

4. Hand-notation:

The use of a system to encode performance with pen and paper. It excludes computers and pocket organisers that recognise handwriting.

5. Computer-notation:

In this study it refers to the use of a notebook touch-screen computer to record all the events. The computer software used allowed the researcher to log the time of each event during real-time and process the data for immediate use.

6. Modelling:

A model presents a structural account of a set of relationships in a pure, abstract, exaggerated form. The act of modelling seeks to create this form and to compare it with the 'real' world. It offers a view of that world by making explicit relationships between concepts and empirical specification. The fit between general principles and specific cases is a measure of the robustness of the model.

1.7.2 Specific terms

Rugby Union

The real-time computer notation collected data within the following groupings:

1. **General /Match Officials:**

   Pre-match data relating to teams involved, type of match, date, venue, and conditions. The referee and touch-judges, with reference to which country they were from.

2. **Territorial Dominance:**

   First-half, second-half and whole match figures were collected regarding the match time, the actual time the ball was in each half of the field and the percentage time the ball was in each half of the field.

3. **Attack Defence Efficiency:**

   First-half, second-half and whole match figures were collected regarding the number of times each side had entries into the opposition 22 metre area, the number of tries they scored, and this was expressed as a percentage to determine each team's attack and defence effectiveness.

4. **Possession Time Base:**

   First-half, second-half and whole match figures were collected regarding the match time, the actual ball in play time, the percentage ball in play time, the actual time each team was in possession of the ball, and the percentage time (of the ball in play time) each team was in possession of the ball. The length of each activity cycle was recorded and was placed in a category according to its length. Both the average and the longest activity cycle were also noted.

5. **Lineout Analysis:**

First-half, second-half and whole match figures were collected regarding the number of lineouts awarded to each team, and then the number won or lost on their own throw as well as the other possible infringements that could occur (penalty for and against, free-kick for and against, not straight, not five metres, own or opposition knock-on).

6. **Scrummaging Analysis:**

First-half, second-half and whole match figures were collected regarding the number of scrummages awarded to each team, and then the number won or lost on their own feed as well as the other possible infringements that could occur (penalty for and against, free-kick for and against, collapsed, wheeled 90 degrees, disengaged).

7. **Rucking/Mauling Analysis:**

First-half, second-half and whole match figures were collected regarding the number of rucks and mauls set-up by each team, and then the number won or lost as well as the other possible decisions that the referee could decide upon (penalty for and against, free-kick for and against, own scrum feed to follow, opposition scrum feed to follow). The number of rucks and mauls lost was automatically added to the number of rucks and mauls resulting in an opposition scrum to give a "turned over" figure.

8. Penalties conceded:

First-half, second-half and whole match figures were collected regarding the number of penalties conceded by each side and in what area of the field i.e. own 22 metre area, own 22 metre to half-way, opposition half-way to opposition 22 metre area, opposition 22 metre area.

9. Kicking Analysis:

First-half, second-half and whole match figures were collected regarding the number of kicks at goal, to touch, from restarts, and in open play and whether or not they were successful.

10. Match Timings:

Each event is logged by time and can be presented in match sequence or in terms of a particular action, for example, lineouts, or a sub-division of a particular action, for example, Welsh lineouts, or even a sub-division of this, for example Welsh lineouts won.

Chapter 2: Review of Literature

2.1 Overview

This chapter reviews the literature on notational analysis of performance in sport and the literature relating to prediction and modelling of performance. The review is divided into three sections:

1. The Development of Sports Notation
2. The Use of Notation in Invasive Team Games
3. Modelling

Where possible the review has been restricted to invasive team field games. For a much wider review of the literature, particularly in relation to racket sports, see Hughes and Franks (1997). For a general review of the literature on the analysis of coaching behaviour see More (1994).

2.2 The Development of Sports Notation

Organised sport with national and international fixtures emerged in the latter part of the nineteenth century. Since that time notation has been gradually utilised in game analysis. Evidence of the early twentieth century origins of sports notation can be found in the work of three pioneers: Fullerton (baseball); Messersmith (basketball and American football); and Reep (association football). All three produced seminal papers that have been under-reported, to date, in academic accounts of notational analysis of sport.

Hugh Fullerton (1910) examined the scores of forty Central League baseball games, twenty-six American League games and fourteen college games in the 1909 season. He reported on the ability of players to work together as a team in baseball particularly whilst fielding when four players covered 180 feet of ground. He recorded the system of signalling used by professional players and how it required intense concentration and memory recall to follow. Some players were able to detect the signals of their opponents during matches forcing them to change their system several times per match. Fullerton (1910) ear-marked the difference between great baseball players and the others as the use of their intelligence to supplement their instinctive play. He concluded "it is the inside game which calls the mind into play to extend the reach of the arms".

There has been very little reference to the importance of Lloyd Messersmith's work and its place in the development of notational analysis. Until recently only one of his papers has been consistently referenced (Messersmith and Bucher, 1939). Lyons (1994) described his contribution to the analysis of performance and has sought to remedy the scholarly astigmatism in relation to Messersmith's work.

In his student days, Messersmith represented the University of DePauw at basketball, baseball and American football. When he graduated in 1928 he was awarded the Walker Cup for outstanding performance during his time at DePauw. In 1930 he returned to DePauw University as freshman coach and assistant in the department of physical education where he coached football, basketball and baseball. He had a sabbatical year in 1942 to complete his doctoral dissertation at Indiana University, entitled *The Development of a Measurement Technique for Determining the Distances Traversed by Players in Basketball.*

He reported in his dissertation how he designed a miniature, scaled basketball court to provide accurate measurements of distances traversed by basketball players in real-time. The court was made of tin with a wooden base, and a tracing wheel was used to follow the movement of a player.

Messersmith's work was an important marker for the scientific credentials of notational analysis. He produced a measurement device to perform some of the first recorded real-time analyses. He provided evidence of how he validated this system and the tests he undertook to confirm the calibration of the tracing wheel (Messersmith 1940, 1942).

Charles Reep has dedicated much of his adult life to the notational analysis of association football. His work was initially used at Brentford and was then successfully utilised by Wolverhampton Wanderers under the management of Stan Cullis, Sheffield Wednesday under the management of Eric Taylor, Watford under Graham Taylor and most recently his work was used as the basis behind the tactical appreciation of Egil Olsen's Norwegian national side.

Reep and Benjamin's (1968) paper was a landmark publication in soccer notation. Reep had notated 3,213 matches in real-time over a period of fifteen years. From those games he had a record of the patterns of play leading up to the scoring of 9,175 goals. He approached Benjamin, a professor of actuarial science, to use statistical techniques to study the passes leading to goals. They used the Binomial Theorem and Probability Theory to compute their statistical data. Their findings indicated that eighty per cent of the goals resulted from three passes or less and fifty per cent of the goals resulted from possession originating in the final (attacking) third of the field.

Reep's findings on goal-scoring encouraged him to think about the territorial aspect of winning performance. He believed that the use of long-balls into the shooting area would create more shooting opportunities (Reep et alia, 1971). Lyons (1996) provides a detailed account of Reep's work.

Fullerton, Messersmith and Reep were pioneers of notational analysis. Messersmith, for example, was the first student to produce a doctoral dissertation in notational analysis. All three were keen participants in sport and what is known of the biographies of Messersmith and Reep resonates with subsequent profiles of notational analysts. The importance of the work of these researchers within the field needs to be fully recognised.

In the United Kingdom, the first wave of the academic development of notational analysis focused after 1970 on racket sports and association football (Downey, 1970; Brooke and Knowles, 1974; Sanderson and Way, 1977; Sanderson, 1983). Since that time the availability of video and computer technology has lead to increasing amounts of lapsed-time notation of performance. Much of the impetus for this work came from the 'new' polytechnics and the nascent sports science departments therein. Workers at

Liverpool Polytechnic and at Sheffield Polytechnic were important catalysts for the emergence of rigorous academic study (Hughes, 1985; Hughes and Billingham, 1986.) Concurrent with this development, Ian Franks established a centre of expertise in notational analysis in the School of Human Kinetics at the University of British Columbia.

By 1992 there was a sufficiently large community of scholars in notational analysis to enable the foundation of an international society. The International Society of Notational Analysts now has over one hundred members and has held three world congresses (1992, 1994, 1996). At the time of completing this thesis, Franks and Hughes (1997) have produced a first text book in notational analysis.

2.3 The Use of Notation in Specific Sports

Notational analysts make permanent records of performance. Data collected by real-time and lapsed-time methods can be analysed during an event, immediately after an event or some time later. The speed at which the data are processed relates to the use that is to be made of the analysis. Fundamental research, for example, has no immediate imperative. However, applied research often necessitates immediate provision of augmented information.

The aim of all sports notation in applied contexts should be to provide triangulated communication between analyst, coach and player which will enable a process of development between the three parties. The relationship between the three should promote empowerment and sharing that would lead to improved learning. Lyons (1993) suggested a relationship where the work of the notational analyst raises the consciousness of the other parties so that they work out their own solutions to the problems. This fusion of thinking and practise he regarded as *praxis*.

Franks et alia (1983) indicated that a systematic approach to analysis can lead to the objective quantification of performance to aid performance. The process of systematic observation provides an objective, reliable, and valid measurement of behaviour. According to Rink (1985) "systematic observation is an analytic process that can provide valid and reliable information on the key elements of effective instruction".

Data can be collected by hand or computer notation systems in real-time or in lapsed-time. Hughes (1988) discussed the advantages and disadvantages of hand and computer notation. It was reported that whilst hand notation is accurate it can involve considerable learning time and have data output procedures that are time-intensive. Computer notation is immediate with relatively easy access to the data and provides the opportunity to present this data in graphical form. Hughes (1988) noted that computer systems do sometimes have operator or hardware or software error. In the intervening eight years since the publication of that paper hand and computer notation systems have been developed that have addressed some of these reported disadvantages. The network of researchers in the field has facilitated cumulative research.

In his 1988 paper, Hughes identified four main purposes of notation: analysis of movement; tactical evaluation; technical evaluation; and statistical compilation.

Notation thus construed can provide immediate augmented information, an extensive database which would offer potential for predictive modelling, and the indication of strengths and weaknesses within teams and performers which can all give an accurate global picture and an overall evaluation of performance.

Notational analysis of performance has been undertaken in a variety of invasive team sports. In the next section of this chapter the work which has had a specific influence on the writing of this study is reviewed.

2.3.1 Rugby Union

The use of notation within rugby union is relatively recent but has progressed substantially since the mid 1980s.

Docherty et alia (1988) analysed twenty seven players during matches to assess the time spent in the various activities of the game. Computerised notation of the frequency and total, mean and percentage times of six activities was undertaken. The players selected were either centre three-quarters or prop forwards: eight players were tracked by four cameras in five minute intervals for a minimum of forty minutes per match. They reported that the players observed spent: 47% of the time walking and jogging; 6% of the time running and sprinting; 9% of the time tackling and competing for the ball; 38% of the time standing; and 85% of the match in low intensity activity. They also noted that centre three-quarters sprinted for 3% of the available time and prop forwards for less than 1% of the time. This research mirrored many preceding notation studies carried out in other sports (Reilly and Thomas, 1976; Green et alia,

1976) and in rugby union (Treadwell, 1988) in that it dealt with time and motion analysis.

Du Toit et alia (1993) made a time, movement and skill analysis for rugby union at senior club level in South Africa in 1987. Three video cameras were used. One followed the match, one followed a forward and one followed a back in each of twelve matches. Their methodology provided the opportunity to compare between positions, over a period of time and to take into account the game situation. Their results indicated that:

1. The length of an average match was 88 minutes 37 seconds.
2. 77% of playing periods were less than 20 seconds.
3. The average play to rest ratio for forwards was 14:22 and backs was 12:24
4. Scrums lasted 5 seconds; lineouts 4 seconds, loose play situations 6 seconds.
5. Forwards moved 3730m; backs 3900m.
6. On average there were 39 scrums, 45 lineouts, 49 loose-play situations.
7. On average there were 35 tackles, 24 running skills, 169 handling skills, 82 kicks out of hand.

Du Toit et alia (1993) cited earlier research by Henri Coupon in the 1970s that indicated that actual playing time in a game of rugby was twenty-seven minutes, but found that many other research papers had different figures for many of the previously mentioned variables. Unfortunately, the methodology of Coupon's research has never been published and this makes it difficult to compare those results with any later research. Clearly there is also a need for precise operational definitions when comparing time-and-motion studies.

Lyons' (1988) analysis of six years of Five Nations' Championship matches to build up a database of game content was an important progression in rugby notation. This large database provided a starting point from which considerable research was carried out. His data were collected by hand notation in real-time.

Lyons and Potter (1993) analysed all 83 matches in the inaugural Rugby World Cup Sevens Tournament to provide benchmark data within this form of rugby and to compare the tactical play with the 15-a-side game. Data were collected by hand notation in real-time at the tournament. Lyons (1995) studied the qualitative issues that arise from quantitative assessments of the game. He analysed the 1973 and 1993 Barbarians v New Zealand matches (both played in Cardiff). It was suggested that although the 1993 match was a much more fluid encounter, it was the 1973 match which captured the public's imagination and has become an icon in rugby memory.

2.3.2 Rugby League

Much of the development of analysis procedures within British rugby league has been influenced by the work of a leading coach. Larder (1988) advocated the use of accurate video analysis in the coaching process. He suggested that detailed analyses could aid the coach in measuring positive factors (tries, breaks, support play, accurate kicks, solid defence) and negative factors (players with unacceptably low work rates or who made errors, had faulty techniques, made incorrect decisions or worked poorly with other players). The two factors that he believed should be measured during every match was possession count and tackle count.

O'Hare (1995) examined the 'success' of Australian rugby league performance in international competition. He identified the 'collision', defined as the time a person is tackled, falls to the ground, stands and brings the ball back into play, as crucial to Australia's success. Australian players are trained to exploit the collision. O'Hare (1995) reported Clarke's use of computerised notational analysis to objectively quantify the collision. Clarke questioned the top forty British players and discovered that eighty per cent of the respondents found the tackle situation the most tiring part of the game. He subsequently notated the 1992 Ashes series and compared Australians and British players at the collision. Clarke (cited in O'Hare, 1995) reported that:

Table 2: Player's actions in an international rugby league match

Players' Action	Australia	Great Britain
Stationary when receiving a pass	16%	30%
Sprint time - receiving ball to meeting defender	2.77 sec	1.69 sec
Sprinting into tackle	29%	5%
Distance gained in collision	1.72	1.28
Three-man defence in collision	4%	13%
Defence stationary in collision	24%	33%

In every aspect of the collision Australia came out favourably. They moved onto the ball quicker and gained more ground each time. They fought hard in the collision to gain an extra yard and commit more opposition defenders to the situation and when it was their turn to defend they would turn the tables, go and meet the attackers and so limit their effectiveness.

2.3.3 Association Football

Charles Reep has spent sixty years notating and analysing association football. He has collected data in real-time live at an event or from a television broadcast. His hand notations provide records of performance from Herbert Chapman's Arsenal team in the 1930s to the European Champions' Cup competition in 1997 (Reep and Benjamin, 1968; Reep et alia, 1971). Some forty years after Reep's first notation efforts a tradition of research in association football emerged.

In the 1970s, Brooke and Knowles (1974) and Reilly and Thomas (1976) undertook time and motion studies of performance in English professional soccer. Reilly and Thomas (1976) analysed the intensity and the extent of discrete activities to specify work rates in different positions. This work is often used as a standard for similar studies undertaken. Reilly (1975) included a substantial amount of notational analysis data in his doctoral thesis in his study of occupational stress in professional soccer. His data were gathered with lapsed-time analysis of video tracks of players at a professional soccer club.

The Football Association have a long tradition of analysis of soccer. Charles Reep established working relationships with Walter Winterbottom, Charles Hughes and Graham Taylor over three decades. He was particularly influential in the emergence of Charles Hughes's views on the game. As Director of Coaching, Hughes had a significant impact on how the game was understood and coached. Much of Hughes's work was presented in *The Winning Formula* (1990).

Elsewhere interest in the analysis of soccer emerged in a number of academic centres. Tom Reilly and his co-workers at Liverpool Polytechnic, George Wilkinson at Newcastle Polytechnic, and Ian Franks at the University of British Columbia were part of a genesis of interest in the analysis of a universal game. By the late 1980s there was sufficient interest in the analysis of soccer to provide an important contribution to the success of the First World Congress of Science and Football (Liverpool, 1986).

Crawshaw and Alderson (1987) analysed the 'half-life' of soccer teams. They cited earlier studies in baseball, basketball and American football that concluded that successful teams changed their players less frequently than unsuccessful teams. Donnelly (cited in Crawshaw and Alderson, 1987) defined the term 'half-life' as the number of seasons required for player turnover to dilute a squad so that only one half of its original members were still present. Crawshaw and Alderson's (1987) investigation into soccer league football confirmed previous research that performance was optimised when the team had a half-life of between five and seven years.

At the First World Congress of Science and Football, Bate (1988), a co-worker with Charles Reep, examined chance, tactics and strategy in football using data drawn from Football League First Division games in 1987. He reported that goals were not scored unless the attacking team played the ball and one or more attackers into the final third, and that the greater the number of possessions then the greater the chance of entering the final third. He sought to refute the concept of "possession football". The higher the number of passes per possession, he argued, the lower the: total number of match possessions; total number of entries into the final third; and the total chances of shooting at goal. He suggested that to increase the number of scoring opportunities teams should: play the ball forward as often as possible; minimise cross-field and backward passes; increase forward passes and runs of forty yards or more; and play the ball into space.

Bate (1988) also cited Charles Hughes' work in the 1980's which stated that 94% of goals at all levels came from movements of four passes or less and that 50-60% of movements leading to shots on goal originated in the final third of the pitch. As part of his analysis, Charles Hughes (1990) divided the field into thirds and looked at the relationship between possessions in each third and the number of goals scored. He suggested that:

Table 3: Relationship between possessions and goals scored in soccer

Pitch Position	Number of Possessions	Goals Originating from Possession	Goals:Possession Ratio
Defending Third	8475	36	1:235
Middle Third	8845	60	1:147
Attacking Third	3553	106	1:34

Hughes (1990) also strongly advocated shooting as often as possible when in the final third of the pitch since "the chances of not losing are even better. We have never recorded a match in which a team achieved ten shots on target and lost". His research led him to advocate 'direct play' and the importance of accurate shooting.

In a discussion about patterns of play in soccer, Franks (1988 and 1989) and Wade (1989) exchanged views on the analysis of performance. Franks (1988) reported that his data indicated that:

1. 1 in 10 shots resulted in a goal.
2. 80% of goals were score from possession of 4 passes or less.
3. Goals came from fewer direct passes than shots.
4. 30-40% of goals came from set-plays.
5. Over 25% of goals originated from crosses.
6. The cross:goal ratio was only 27:1

Wade (1989) criticised an underlying assumption of Franks' (1988) paper that soccer success is measured on a win-lose basis. He suggested that it could be measured on a win-lose continuum but not on a strict win-lose basis. He questioned Franks' statement regarding the aim of the team in possession being to score goals. He suggested that some teams have been intent on using possession to simply prevent the opposition from scoring or to kill time. Wade (1989) also criticised Franks' (1988) statement about the shot:goal ratio over thirty-five years being 10:1. He believed that data collected was of little importance to current performance and that these data might be seriously flawed because different analysts will have their own subjective view over the definition of a shot. He also questioned Franks' (1988) statement regarding goals coming from four passes or fewer since most of the game is made up of passing movements of this dimension.

What Wade did not recognise was that one of Franks' main aims was to demonstrate that it was possible for coaches to have accurate and in-depth information available to assist them in their decision-making. Many coaches in the past have reacted to their recall of what has transpired and this is often inaccurate. Wade also based much of his critique on personal opinions and experience and whilst there has to be a realisation of the importance of such knowledge, Wade did not use any factual basis to support his views.

Partridge and Franks (1993) designed an intervention study to enhance performance in soccer. They suggested that:

> quantitative notational analysis accompanied by edited videotape excerpts of a performance, could provide athletes with the sort of accurate and reliable feedback that is vital to the learning process and which is highly valued by athletes themselves.

They employed a computerised system to record and monitor performances of individual players and then used the data gathered to change (enhance) players' performance.

The Norwegian national coach, Olsen, and Larsen (1997), discussed the need for closer links between 'academic' and 'practical' research and cited this as a key reason for Norway's success in international football in recent years. They realised what Franks (1988) had purported, that a coach needed objective information to assist them in the recalling of events and the subsequent deliberations. Their aims in analysing performance were:

1. To measure the team's effectiveness through counting scoring opportunities.
2. To measure the types of attacks and their efficiency.
3. To gain more knowledge about the match syntax in general.
4. To have a quantitative and qualitative analysis of each player.

Olsen and Larsen (1997) described the use of match analysis in Olsen's preparation as a national coach. Although defence was generally not influenced by match analysis, attacking tactics were initially fuelled by the work of Reep and Benjamin (1968). The attacking tactics employed involve a more penetrative means of moving forward and if an unbalanced defence is met, that is, after a breakdown then this imbalance is not allowed to decrease as the attack progresses. This pattern inevitably involves more losses of possession but also greater number of shooting opportunities. Against a balanced defence long ball play is employed.

The Norwegian FA wanted to build a computer analysis system to provide a database of matches and players and make the video interactive with it. They wanted to extend their post-mortem beyond the end result and measure efficiency in terms of scoring opportunities and types of attack. In four years (1991-1994) Norway scored 71 goals in 44 matches from 332 opportunities, a ratio of 1:4.7. Their opponents scored 29 goals from 186 opportunities, a ratio of 1:6.4.

Yamanaka et alia (1997) analysed the performance of the Japanese national soccer side in its qualification games (n=8) for the 1994 World Cup. They collected 32 different actions and entered each according to time, place, player and action. They looked at 13 variables and performed a chi square test for significance. The only statistically significant differences were that Japan dribbled more often than Saudi Arabia and Korea, passed more than Saudi Arabia and cleared the ball more than Iraq. There were no major differences between the teams in overall statistics so the study looked into frequencies of passes in certain areas of the field. It revealed that Japan passed more in offensive areas than the other teams. Previous research by Hughes et alia (1988) showed that successful teams used the central area immediately in front of the opponent's goal more effectively. Unsuccessful teams used the flanks more. From the data of Japan's matches the conclusions were made that Japan's performance was defence orientated and was unstable. The overall conclusion was that Japan needed to establish a flexible approach to its tactics.

Luhtanen et alia (1997) suggest that for teams to win they must have effective methods of winning the ball, creating successful attacks that reach the final third, create effective scoring chances and score the goals efficiently. For each action the time and spatial co-ordinates were noted, and times in possession and distance covered by the ball, and qualitative manoeuvres (attacking trials for the attacking third, scoring chances created, scoring trials, and goals). A reliability study was undertaken on one match and the two independent experienced analysers found that the differences for the 6 variables were 2.1%, 3.5%, 3.5%, 6.4%, 0% and 0%.

According to their findings Brazil were the strongest side in the World Cup. They had the highest number of attacks in the attacking third, the highest number of scoring chances in the vital area and the highest number of shots for scoring goals. They dominated on average according to time (56%), distance (63%), attacks in the attacking third (65%), number of scoring chances (73%), scoring trials (71%) and goals (80%).

Garganta et alia (1997) studied how elite teams played in order to identify patterns and to establish a group of indicators. They described and compared positive offensive actions from the time the ball was gained or regained up until a shot on target. A lapsed-time hand-notation system was used to investigate five European teams and 104 goals in 44 matches. Bate (1988) found that 50-60% of all movements leading to a shot on goal originated in the attacking third. Hughes (1990) claimed that a goal was scored for every 34 possessions regained in the attacking third but only in every 235 possessions gained in the defensive third.

Garganta et alia (1997) found that:

1. Over 50% of offensive actions leading to a goal were within 10 seconds of receiving possession.
2. In 47.7% to 85.0% of the goals only 1 to 3 players touched the ball.
3. Between 61% and 93% of the goals involved 3 passes or less.

The overall conclusion of the study was that European top level sides, in scoring movements, win the ball in their attacking third then have a short attacking reaction time involving few players and few passes.

Miyamura et alia (1997) examined the time the ball was in play and out of play in a cross-section of women's soccer matches and compared them with men's soccer. The matches analysed were four matches from the final rounds of the FIFA Women's soccer World Cup, three matches from the 8th Asian Women's Championship, one final of the Junior women's league and one from the University Cup. Post-event hand notation was used. The findings showed that the ball-in-play times were significantly lower in women's football and also down the scale within the matches analysed the ball in play time dropped. Passing continuity were constant with the previous research on men's matches.

2.3.4 Gaelic Football

Research in Gaelic football has followed methods used in other invasive games. One noticeable aspect of the game is that scoring occurs frequently (approximately every three minutes). Keane et alia (1993) sought to identify players' work-rates. Data were gathered on sixteen players in eight matches. Two players were filmed in each match. They reported that:

1. The mean distance covered by players was 8594 metres, of which 35% was walking, 32% jogging, 12% striding, 4% sprinting, 2% in possession of the ball and 17% moving backwards or sideways.
2. The distance covered per activity ranged from 10.6 metres to 13.5 metres.
3. There were only minor differences observed between positions.
4. There was no significant differences between first and second half in terms of distance covered.

2.3.5 Netball

Along with soccer, netball has a long tradition of analysing performance. Elliott and Smith (1983) studied netball shooting during a whole season and recorded the percentage accuracy and the distance away from the hoop. Their study was based upon the earlier works of Embrey (1978) and Barham (1980).

Otago (1983) completed a study similar to that of Reilly and Thomas (1976) in association football. The research investigated the characteristics of each playing position in relation to type of activity, lengths of activity and work to rest ratios. Twenty four international players were analysed from videotaped recordings of two matches. Among the findings were that players in the same position demonstrated different activity patterns; certain position could be grouped together in terms of activity time (GK and GS, GD and GA) but not in terms of activity pattern; centres are most active, the majority of work periods were under ten seconds; work to rest ratios were 1:3 or greater. Otago (1983) also noted that: players in the same position demonstrate different activity patterns depending on their own team's and the opposition's tactics; each position has unique activity patterns; the centres were the most active; defenders spent most of their time "shuffling"; the anaerobic system is dominant.

Steele and Chad (1991) quantified the movement patterns of skilled netball players in order to determine whether training drills were tailored to the demands of individual positions and whether the demands of training games were similar to those of match play. Analysis covered one match and two training sessions for four teams. The movement patterns were coded directly onto a computer using a specifically designed software. Analysis of the movement patterns showed significant differences between positions in match play, but that the training drills did not cater adequately for the demands of the different positions. The training games though did replicate the demands of match play in terms of average time per activity, and the percentage time allocated to each activity. Steele and Chad (1992) then developed their findings to design a training program based on the physiological demands of each position. They further developed Otago's (1983) work by using lapsed-time video analysis. Four matches were analysed using two videos and a Time-Motion Analysis computer program. Movement patterns were classified according to locomotor and non-locomotor activities.

Fuller (1988) developed and designed a computerised Netball Analysis System and focused on game modelling from a data base of twenty-eight matches at the 1987 World Netball Championships. There were three main components to her research: to develop a notation and analysis system; to record performance; and to investigate those performance patterns that distinguish winners from losers. Her system notated how each tactical entity started; the player involved and the court area through which the ball travelled; the reason for each end of possession; and an optional comment. The software provided data outputs on: shooting analysis; centre pass analysis; loss of possession; player profiles; and circle feeding. This work is further discussed in the review of modelling strategies later in this chapter.

2.3.6 Basketball

In addition to the doctoral dissertation described earlier, Messersmith also published a series of papers linked to his empirical research. Most of this work was written with co-authors.

Messersmith was fascinated by the work rates of players and the impact of rule changes on these rates. Fay and Messersmith (1938) reported that the distance traversed by players had increased with rule changes of that period and players covered between 3.87 and 3.97 miles as compared to 2.25 to 2.5 miles in 1931. Messersmith and Bucher (1939) noted that the distance traversed by Big Ten players were similar to those travelled by Indiana collegiates, and that college players travelled more than school players. He also compared the distance traversed by collegiate men and women (Messersmith, Laurence and Randels, 1940). In a sole authored paper (Messersmith, 1940), describes the development of a recording instrument and the study of 200 individuals on three different sized courts. He found that college players travelled an average of 3.34 miles per game or an equivalent of 441ft per minute; there was no significant difference according to position and rule changes did have an effect on distance travelled. Over a 32 minute period, men covered an average of 2.17 miles and women 1.03 miles.

Miner et alia (1940), contemporaries of Messersmith, studied women's basketball and the time spent in active play as well as the distance traversed. They compared guards and forwards and noted that guards travelled less and were involved in active play less and that the distance traversed by a superior player was dependent on her and her team's skill rather than the type of game played. The distance covered by a floor guard was 2.34 miles and on average offensive players travelled twice that of defensive players.

Tharp and Gallimore (1976) examined the coaching method of John Wooden. At that time he was regarded as the greatest coach in the history of basketball. He was the only person ever inducted into the Hall of Fame as both a player and coach. Wooden's system of basketball required the basic fundamentals of discipline, hard work, selflessness, and control but it also involved a concept for character building which he called the "pyramid of success".

Southard and Miracle (1993) examined free throw shooting in basketball and the effect of rhythmicity on results. They found that consistent periodicity/rhythmicity of performance ritual behaviours was more important to free throw success than maintaining the absolute time of rituals. They cited Cooper and Andrews (1975) who had suggested that "performers develop consistent patterns of performance with subconscious, albeit persistent rhythmic patterns."

2.3.7 Field Hockey

MacHeath (1987) suggested that notational analysis could be used in hockey "to provide coaches with more precise detail in a more concrete form to consider alongside their own observations of the happenings on the pitch". Some years earlier, Wein (1981) had emphasised the importance of audio-visual techniques for the analysis of performance. He advocated the use of video in competitive matches to bring about improvements in individual and team performances. This approach enabled: a study of the opposition which could prepare a team both tactically and psychologically; experiencing and understanding one's own mistakes through selected feedback; empowering individuals on how to best resolve a given situation and widen their experience.

Wein (1981) studied the Second men's hockey World Cup in 1973 in Amsterdam, and also compared it to the 1974 soccer World Cup.

Table 4: Comparison of activity time in hockey and soccer

	Hockey World Cup 1973	Soccer World Cup 1974
Ball in play (%)	53	66
Activity Cycles (70 mins)	230	93
Average length of cycle	16 seconds	8.7 seconds

Wein concluded that the average ball in play time in the hockey World Cup was 37 minutes 16 seconds and argued that this time would decrease the lower the standard of hockey played. He divided the ball in play times according to the two halves and found that in hockey the ball was in play for longer in the second half whereas in soccer it was in play longer in the first half. Wein (1981) also undertook a time and distance analysis of one player in the World Cup. He discovered that one player was involved in direct action for 20 minutes and 36 seconds (30% of the match time). During this time he covered 5610 metres (81 metres per minute). He further sub-divided his study to look at defenders (5140m), mid-fielders (6300m) and attackers (8818m). Sixty one per cent of the activities lasted between 0.5 and 2 seconds, and only 5% lasted over 7 seconds. He found that a free-hit or push-in on average occurred every 18 seconds and that 40% of these push-ins did not reach a player of the same side.

Wein also analysed matches in the Intercontinental Cup and the Asian Games. In one match between Italy and Mexico during the first ten minutes both sides lost the ball a total of 81 times and of 23 free-hits only four reached a player of that side. In a match in 1970 between Pakistan and Thailand, Pakistan were off-side 31 times, 18 in the first half and 13 in the second. In addition there were 21 stick offences in the first half. In the Malaysia v Singapore match there were 36 stick offences in one half. In the

Montreal Olympic Games of 1976 an average hockey match there were only 6 to 10 shots from open play. He also noted that there was no significant relationship between frequency of goals and duration of a game, but it seemed that there were more goals scored in the second half than in the first half, especially towards the end of the game.

Wilson (1987) undertook a study of forty-two games at the women's' 1986 World Cup. She argued that "the availability of objective, quantifiable data is necessary for comprehensive performance analysis in hockey". She further suggested that a data base of performance: allows for comparisons both within and between teams; facilitates the establishment of performance standards; and creates the possibility of forming predictive models. She used a computer based analysis system, the Computer Assisted Sports Evaluation System (CASE) for Field Hockey. Wilson notated the number of shots and their outcomes, since "the ultimate empirical result of successful attack performance is the scoring of goals."

She discovered that from the 825 shots in the tournament, 147 resulted in goals: a shot to goal ratio of 5:1. This might suggest that teams should maximise the number of shooting opportunities but this cannot be the only aim. For instance, Australia had the most number of shots but did not win the tournament. They scored 25 goals (the most in the tournament) from 117 shots (the most in the tournament). There is also a need for a qualitative analysis of defensive performance of a team.

Of the 147 goals, 61.2% resulted from set-pieces in the attacking zone. The remaining 38% originated from free-play. As well as analysing the events leading to goals she also looked at the events immediately after a shot at goal. She found that shots often lead to long corners but also free-hits to the opposition and that 10% of all the penalty corners resulted in goals. Importance is attached to penalty corners in hockey and this might be over-emphasised slightly since Wilson's findings show that when the data are standardised then there is a greater chance of scoring goals from other set-pieces. The key would then be to produce more of these other set-pieces. Of the penalty corners analysed 97 (16.3%) resulted in opposition possession and 62 (10.4%) in goals scored. Of the 97 opposition possessions, 79 were free-hits. Another conclusion was that left-sided approaches were more effective than central or right handed approaches.

2.3.8 Lacrosse

In Britain there is a tradition of research in women's lacrosse dating back to the early 1980s. Brackenridge reported her use of notational analysis in lacrosse (Brackenridge and Alderson, 1985). She used a mixture of audio-taped commentary followed by hand and computerised notation of the transcription in a system she referred to as BRACSTAT. More recently, Lyons (1995) and Sharpe (1997) have undertaken research into patterns of play at the 1993 Women's World Cup.

Weinberg et alia (1994) studied the effects of a specific goal-setting programme on physical performance over the duration of a season. Twenty four male lacrosse players were selected and assigned to either a goal-setting or do-your-best control group. A number of performance variables were measured. Although there was no statistical significance between the two groups, the size and direction of the differences in favour of the goal-setting group did offer support for the potential goal-setting for lacrosse players.

2.4 Modelling

There is a growing literature on modelling performance in sport. As indicated in the introductory chapter, modelling and prediction have been part of notational analysis's epistemological aspirations since the 1980s. The challenge has been to deal with what Morris (1981) identified as a fundamental problem, that "every match is a contradiction, being at once both highly predictable and highly unpredictable".

Recently, Franks and McGarry (1996) have suggested that the modelling of competitive sport is an informative, analytic technique because it directs the attention of the modeller to the critical aspects of data which delineate successful performance. They add that "the modeller searches for an underlying signature of sport performance which is a reliable predictor of future sport behaviour".

Teams and performers appear to demonstrate stereotypical patterns of play. Detailed analyses of these patterns can generate databases that can provide a foundation for models of performance. Some time ago, Mosteller (1979) set out guidelines for a predictive model of performance:

1. Use the past to predict the future -use only past scores to predict future ones.
2. Use weights - weigh recent games much more largely than games earlier in the season.

3. Use last year's data - for early games one would weigh up last year's last few games. As season progressed, last year's games would have less weighting.
4. Estimate strengths and weaknesses.
5. Adjust for home and away.
6. Adjust for trends such as injuries and evident strengths.
7. Develop scores for injuries.
8. Consider morale.

Some decades before this work, Soule (1957) reported on work carried out by the team statistician of the Brooklyn Dodgers baseball team, Roth, notated half a million symbols per year and prior to each match calculated the probability of his team winning on a given park, on a given day, with a given pitcher.

Franks and McGarry (1996) cited Charles Reep's work in soccer and how statistical analysis of his data reveals mathematical functions and consistencies of certain behaviours. The conclusions drawn from their work suggested that it would be of benefit to a side to maximise the probabilities of certain actions at the expense of others. Reep and Benjamin (1968) found that the goal:shot ratio was 1:10 and thus thought it would seem fair to suggest that an increase in the number of shots would lead to an increase in the number of goals. Since they also found that most shots came from passing movements with very few passes then the 'long ball' or 'direct style' of play should become an important strategic investment. Franks (1988) found that passing movements leading to goals were even shorter than passing movements leading to shots, hence suggesting that there lies a sub-group within the shots on goal group.

Another of Reep and Benjamin's (1968) findings was that over half of all shots arose from regained possessions in the final third of the field. This finding was reinforced by Partridge and Franks (1991) who found that West Germany, winners of the 1990 tournament, lost the ball most regularly in the final third (61%). Reep et alia (1971) expanded their previous research to see whether the negative binomial distribution was also applicable in other sports. They used the analogy of Greenwood and Yule's (1920) model for accidents to industrial workers to prove that in Poissonian situations good fits were obtained but that these fits diminished when studying sports where individual skill played a bigger role.

Fuller (1988) developed and designed a Netball Analysis System and focused on game modelling from a data base of twenty-eight matches in the 1987 World Netball Championships. The routes that winning, drawing and losing teams took on court was notated and she interrogated her data base to identify significantly different patterns of play. From her results, Fuller was able to differentiate between the performances of winning and losing teams. Differences were technical and tactical. She identified nine quantifiable benchmarks:

1. Shooting efficiency for the Goal Shooter (GS) for winning/drawing teams bettered 73%.
2. Shooting efficiency for Goal Attack (GA) for winning/drawing teams bettered 65%.
3. GA attempted 42% of all shots with winning teams.
4. Shooting efficiency bettered 54% for winning/drawing teams from inner region.
5. Winning/drawing teams created 57% of shooting chances directly from own centre plays.

6. Winning/drawing teams scored 70% of shooting chances from own centré plays.
7. Winning/drawing teams lost on average 72 and 53 possessions per match respectively.
8. Winners lose 20% of possessions in the defending and centre third areas.

Fuller's (1988) research was an attempt to model winning performance in elite netball. She recognised that more research was needed into qualitative aspects of play, for example, how more shooting opportunities are created. She also suggested that the model should be used to monitor on-going performance over a series of matches not as a snapshot of one-off performances.

Alexander et alia (1988) used the mathematical theory of probability for their study of squash. They suggested that mathematical modelling can describe the main features of the game and can reveal a player's strategic patterns. A specific benefit of this ability to predict would come into effect when a player was faced with the choice of setting or not when the game reached 8-8. The hand-out would be able to choose whether to call for a set or not.

They noted that performance in squash is an example of a Markov Chain. This they expressed as:

The probability that A wins a rally when serving is	Pa
The probability that A wins a rally when receiving is	Qa
The probability that B wins a rally when serving is	Pb = 1 - Qa
The probability that B wins a rally when receiving is	Qb = 1 - Pa
If two opponents are of the same standing then	Pa,Pb,Qa,Qb = 0.5

The probability that A winning a point when serving is the sum of each winning sequence of rallies:

$Pa = 1/2 + 1/2^3 + 1/2^5 + 1/2^7 + \ldots = 2/3$ (geometric series)
Pa wins 9-0 = $(2/3)^9 = 0.026$
If A is stronger player with $Pa = 2/3$ and $Qa = 3/5$ then:

Probability that A wins when serving is 5/6; when receiving is 1/2.
Probability of A being in a serving state is 3/4.

The probability of winning a game is the sum of all the probabilities of each possible score, i.e. sum of p (9-0), p (9-1) . . . . p (9-8), p (10-9).

Treadwell, Lyons, Potter (1991) argued that match analysis in rugby union and other field games had centred on game modelling and that their research was concerned with using the data to predict the game content of rugby union matches. They found evidence of physiological rhythms and strategic patterns. They suggested that at elite level it was possible to identify key 'windows' or vital "moments of chronological expectancy where strategic expediency needs to be imposed." They indicated that international matches and successful teams generated distinctive rhythms of play which were akin to a fingerprint or heartbeat of performance. Lyons (1988) had previously analysed six years of Five Nations' Championship matches to build up a database, and from this was able to predict actions. In the case of a Calcutta Cup match between England and Scotland in 1988, for example, he was able to predict the game content within 3 passes and 2 kicks of the actual performance. Franks et alia (1983) had previously stated that they felt that one of the most important uses of quantitative analysis was the formation of a data base of past games to provide the possibility to formulate predictive models.

Grehaigne (1996) analysed configurations in football according to positions of the players, their speed, and their directions. From these data he proposed a model to analyse the transition between configurations of play.

Franks and McGarry (1996) described how sports analysis can move on from being a descriptive process to becoming a predictive one. If there is some level of consistency within the performance then future performance can be predicted from past matches through stochastic modelling. They sub-divide sports into two sections, those determined by score (squash, tennis, etc. where the result is win or lose) and those by time (soccer, rugby, etc. where the result is win, lose, or draw.) This is an important distinction when modelling is to be discussed.

The characteristics of score-dependent sports are based largely on a structured sequence of discrete events where the relationship between each event is related to the opponent. Time-dependent sports are invasive and interactive and can be considered as relatively contingent in a temporary state. The structure of the sport is very important when it comes to deciding what method of modelling one should use to predict performance.

Score-dependent sports can be modelled by simply using discrete event models but the time-based sports need time models since the next event is always dependent on both event and time. Franks and McGarry (1996) suggested the use of the so-far untried Poisson model for discrete events in time-dependent sports. They also discuss the importance of the number of competitors involved in a sport for the development of a model: the greater the number of competitors then the larger the scope for variability.

This illustrates the problems facing coaches when they view a game. It would appear to be the case that the previous event only becomes of importance to the coach when a critical event has just occurred. The amount of data generated by the analysis of team games is one fundamental reason why comparatively little modelling has emerged in these time dependent sports.

Beyond the academic confines of notational analysis, theorists have explored a range of models to explain behaviour. These theories include: catastrophe theory; chaos theory; and critical incidents.

2.4.1 Catastrophe Theory

Kirkcaldy (1983) described catastrophe theory as:

> a descriptive model . . . which allows us to better appreciate the manner in which *multi-dimensional* systems operate and to make predictions of the behaviour of the systems under scrutiny.

Kirkcaldy cited Thom (1975) who originated the mathematical model and Zeeman (1975; 1976) who later modified it. Kirkcaldy (1983) used the model to provide a possible explanation of how explosive effects can accompany small changes in arousal to produce an optimum level of performance or a sudden decrement in performance. It is concerned with the methods of attaining equilibrium states in qualitative mathematical language.

Poston and Stewart (1978), in Kircaldy (1983) stated:

> Catastrophe theory may be expected to give useful analyses of more widely varying data than do the current linear models. Of course, it requires the development of comparable statistical expertise for the essentially non-linear case before that expectation may be fulfilled.

Thom's (1975) 3-dimensional model of catastrophe has been used in sport in an attempt to explain the relationship between cognitive and somatic anxiety and athletic performance, and to predict performance from this. Catastrophe theory predicts a negative linear relationship between the cognitive anxiety and the performance, but that the somatic anxiety also plays a role. Hardy (1990) hypothesised that if somatic anxiety increases towards optimum while cognitive anxiety is low then performance will be facilitated.

2.4.2 Chaos Theory

The ability to predict performance is an inherent part of the process of effective planning, but accurate forecasting can be difficult. Errors in statistical methods of prediction are often attributed to forecasting error but chaos theory suggests that those errors are better explained by non-linear rather than the more traditional linear mathematics. Proponents of chaos theory suggest that it is the science that discovers order in nature's seeming randomness.

In more recent times scientists have discovered that certain systems within nature have chaotic dynamics and have an infinite variety of unpredictable forms but through a systematic process of self-organisation. The disorder of nature produces orderly patterns such as snowflakes. Other examples of non-linear chaotic systems are: weather, national economies, fibrillating hearts. An "attractor" graph is one way to demonstrate how a chaotic system's solutions converge towards a specific path. A small change to the input will vary the pattern. Although this variation appears to be chaotic and random it is a reflection of a high order of complex events within phase space.

A number of researchers have explored whether this pattern of chaos and self-organisation could also be evident in human situations. Stacey (1993), for example, examined the possibility of using this new frame of reference in the management sector. His investigation was based upon an awareness that the behaviour of some systems within nature is so complex that the link between action and outcome simply "disappears in the detail of the unfolding behaviour."

In the management of human organisations, chaos theory points towards the need for managers to create an unstable environment for effective learning and hence new strategic directions to evolve. There are certain key points on the behaviour of dynamic systems and their applicability to human situations. Stacey (1993) suggested that:

1. Chaos is a fundamental property of non-linear feedback systems. All human behaviours are non-linear because one action always leads to a subsequent one and people tend to over or under react. Therefore in any situation involving human interaction there is a possibility of chaotic behaviour as well as stable or unstable behaviour. The key question is which state leads to successful performance. Success will lie at the border between a state of stable

equilibrium (ossification and team work) and an unstable state of equilibrium (disintegration and individual performance), i.e. in a non-equilibrium state between the two.

2. Chaos is a form of instability where the future is not known. When irregular patterns of behaviour operate away from equilibrium they will be highly sensitive to tiny changes and will completely alter the behaviour. Small changes leading to larger ones are common place occurrences in human situations.

3. Chaos has boundaries around its instability. Chaos is disorder and randomness at one level and qualitative pattern at another. When the future unfolds it often repeats itself but never in exactly the same way. "Chaos is an inseparable intertwining of order and disorder".

4. Unpredictable new order can emerge from chaos.

Priesmeyer and Baik (1989) used chaos theory to describe the performance of companies. They describe their organisational heartbeat as "quarter 1, quarter 2, etc.". What chaos suggests is that a certain cycle will be followed over time but that there may be a divergence from this pattern in response to any environmental changes. One company, Toro, which manufactured snow-throwers experienced a change to chaos. In the winter of 1979 the USA had limited snowfall, shocking the company from a stable period one pattern to a chaotic behaviour pattern and then to a more stable one again. This transition back to a stable pattern represented successful dampening of the chaotic condition.

At the time of the Euro 1996 association football championships, O'Hare (1996) discussed the possibilities of using chaos theory to explain, model and predict behaviour. He interviewed two co-workers, Lyons and Hughes, from the Centre for Notational Analysis at the University of Wales Institute, Cardiff. O'Hare (1996) suggested that chaos could be used as a metaphor for thinking about how association footballers could move from established patterns to new patterns of play. The co-workers were at pains to emphasise that the use of chaos theory in team sports required a detailed understanding of the mathematics of phase space and that to date there was little work in this complex area. Hughes (cited in O'Hare, 1996) identified the potential of 'perturbations' to develop an understanding of chaos in association football.

2.4.3 Critical Incident Technique

Critical Incident technique was developed in the United States of America by Flanagan (1954) to identify why student pilots were failing at flight school. The technique was further developed at the American Institute for Research to continue "the systematic research on human behaviour in defined situations." Flanagan defined the process as:

> The critical incident technique outlines procedures for collecting observed incidents having special significance and meeting systematically defined criteria.

Some research on the pilots was initially undertaken by Miller (cited in Flanagan, 1954) and he concluded that pilots were eliminated from training for such reasons as poor judgement or insufficient progress. The critical incident technique according to Flanagan (1954):

> consists of a set of procedures for collecting direct observations of human behaviour in such a way as to facilitate their potential usefulness in solving practical problems, with emphasis on observed incidents possessing special significance.

The incidents noted are those that the observer believed to be both crucial effective and crucial ineffective behaviours. These incidents are then categorised according to the behaviours to constitute the critical requirements. Flanagan saw the technique as a flexible one which should be modified to meet the specific needs of any given situation, and research has been made not only with pilots but also with nurses, teachers and administrators.

Jensen (1951) found the critical incident technique to be a sound, objective way of collating information, as did Merritt (1954):

The critical behaviours are derived from the reporter's description of actual teaching incidents, rather than their value judgements about critical teaching behaviours.

The critical incident technique is a powerful research tool but as with other forms of notating behaviour there are limitations inherent in the technique. Flanagan (1954) admitted that "critical incidents represent only raw data and do not automatically provide solutions to problems"

Another limitation of the technique is the total dependence on the reporters' opinions and this subjective element is often stated as a disadvantage but Flanagan (1954) also pointed to the advantages of such a technique:

> The critical incident technique, rather than collecting opinions, hunches and estimates, obtains a record of specific behaviours from those in the best position to make the necessary observations and evaluations.

Barclay (1968) used the critical incident technique in teaching beginners to swim. His methodology included a questionnaire asking both the teachers and the students to identify, if possible, two specific critical incidents which they believed to have helped and hindered the instruction. In his pilot study of 30 students, 48 critical incidents (28 effective and 20 ineffective) were indicated.

A critical incident was used as long as the criteria laid down were met:

1. It described an actual happening observed or participated in by the observer.
2. It took place in beginning swimming instruction.
3. It included a clear description of teaching behaviour.
4. It showed a teacher behaviour/student outcome relationship.

Barclay (1968) tested for reliability by asking two judges to abstract critical behaviours from the same 50 incidents. Judge 1 identified 62 behaviours and agreed with the investigator on 85.5 % of the behaviours identified. Judge 2's corresponding figures were 68 and 88.9%. In the study a total of 1505 critical behaviours were extracted from the critical incidents: a 929 effective behaviours/576 ineffective behaviours split.

Garis (1966) aimed to identify both ineffective and effective teacher behaviour in gymnastic instruction and thus establish specific guidelines for effective teaching. Over three thousand schoolgirls and over two hundred teachers from New York state were used in the research. The research:

1. Tested the reliability of the abstracting process
2. Identified and abstracted the critical behaviours from the incidents.
3. Categorised the critical behaviours.

This enabled Garis (1966) to establish a set of conclusions based on the critical incident technique which would provide a guideline of effective teaching for gymnastic activities to girls.

More recently, Hughes, David, Mills and Dawkins (1997) have explored how critical incidents (perturbations) can be used to analyse and model goal-scoring in association football. At this stage their work is exploratory but they suggest that such an approach can further understanding of changes in performance. At the time of completion of this thesis, Franks and Hughes (1997) were developing the conceptualisation of critical incidents from their mutual interest in squash rackets and association football.

Chapter Three: Methodology

3.1 Introduction

In the last decade there has been increasing interest in the sports science community in linking fundamental and applied research studies. In the United Kingdom, for example, the British Association of Sport and Exercise Sciences (BASES) has encouraged interdisciplinary study as one means of linking theory and practice. This study seeks to further this integration. As indicated in Chapter Two this study has been framed by discussions with a focus group of 'experts' interested in the analysis of performance. Throughout the research there was close collaboration with this group of national and club coaches, players, administrators and sports scientists. Meetings were held with individuals and groups to discuss and establish criteria for the analysis of performance. This approach was also evident in a seminal research report produced by Franks and Goodman (1984).

The background to the research design and procedures used in this study was outlined in Chapter One. It was noted there that real-time systems were to be central to data collection. In this section the design and validation of these systems are discussed

3.2 The Notation Systems

The research used real-time hand and computer notation to collect data. The hand notation systems were developed as research instruments by the researcher over a period of four years (1989-1993) to the final stage which was used in the research. The computer notation systems were developed as extensions to the hand notation systems. They were programmed in the Visual Basic computer language.

The use of the hand notation systems was considered to be an essential part of the whole research process. They were based upon a tried system which had been tested rigorously for validity and reliability at an earlier stage. The hand notation systems used in the study are presented in Appendix C. Care was taken to colour code data entries in these systems so that sequences of events could be captured. Examples of these data are presented in Appendix C.

The real-time computer notation was designed as a time-based system. This was an important characteristic as it enabled data collected to be related to game situation in terms of both time and score. The computer analysis allowed the sequential history of game events in rugby union and association football to be logged. For further information regarding this system see Appendix C.

The computer notation system was designed to provide an innovative approach to data collection, analysis and presentation. In rugby union, a wealth of data were collected during the 1995 Rugby World Cup and there was an obvious need to graphically represent these data. The requirement was to achieve a level of graphical excellence through which the complex ideas of the research could be communicated with clarity, precision and efficiency. In addition, there was also a need to maintain a level of graphical integrity where the graphics did not quote the data out of context.

Graphical excellence, according to Tufte (1983) is:

> The well-designed presentation of interesting data - a matter of substance, of statistics, and of design ... gives to the viewer the greatest number of ideas in the shortest time with the least ink in the smallest space.

Graphical integrity requires clear, detailed and thorough labelling of graphics that illustrates data variation not design variation and the representation of numbers that are directly proportional to the numerical quantities represented. Tufte (1983) argued that graphical displays should: illustrate the data; induce the viewer to think of substance; avoid distorting what the data says; present many numbers in a small space; make large data sets coherent; encourage the eye to compare; and reveal data at levels of detail. Cauraugh et alia (1993) suggested that graphic knowledge of results facilitates acquisition and retention of data more than numeric information.

With these graphical imperatives to the fore, it was decided to develop a 'game signature' output of data compiled from relational databases in the computerised system. Data input and output design issues converged on this form of representation. The development of the computerised system comprised a number of stages.

The initial stages involved pen and paper drafting of graphical output before moving onto a computer to input data and to use a spreadsheet to produce that output. The opening match of the 1995 Rugby World Cup between South Africa and Australia was used as the pilot study for this process.

It was decided to divide the game into ten-minute intervals (five of these for each half of the game). At this stage it was also decided to represent at the top of the graph a game rhythm that comprised: a 'bar code' of the time the ball was in play in the game; which team was in possession of the ball; territorial dominance; and scoring sequence. The teams were colour coded to match their playing colours. In all, six different graphs were produced that were related to the game rhythm and provided data on: continuity of play; performance indicators; set piece play; loose play; and patterns of play.

This pilot study revealed that for each of these aspects a minimum of eight graphs would be required. It was decided that in order to reduce the number of graphs there would be merit in illustrating the data not according to match time but to ball in play time. This would reduce the number of graphs to a maximum of four per aspect. This produced another problem, however, in that there was now no way of relating each activity cycle to the inactivity of the teams and players. This would lead to an incomplete account of performance and compromise the graphical integrity of the data.

The problems therefore remained that for one match in the World Cup a total of approximately 50 graphs would be required and in excess of 1500 for the whole tournament. The method was also time intensive and for any future match data processing and graphical output would take approximately 20-25 hours for one game.

The next stage was to devise a method which would alleviate the problems encountered during manual data processing. What was required was a means of instantly processing the data gathered by computer notation in the World Cup to produce graphs, the design of which was already fairly satisfactory. Using the same programming language as used for the computer notation systems, Microsoft Visual Basic 3, an extension to the 'viewing' aspect of the software was developed which produced the 'Game Rhythm' graphs required. The layouts were largely the same but now a whole half of a game could be incorporated into one graph, and also each variable could be displayed on the one graph. One half of a rugby game in the World Cup could be instantly accessed and displayed either in numerical or graphical form. The total number of graphs for the World Cup could now be reduced to 64. The programme also incorporated a zoom function which allowed for a selected portion of the graph to be examined in detail. The data for either team or the combined data could be accessed. (The first half and second half graphs for this match are shown in Appendix C).

The graphs present the viewer an instant storybook of one half of rugby. The flow of the match can now be followed from beginning to end and each team's performance in key areas such as lineouts, scrums, rucking and mauling, discipline, attack and defence can now be related to their position on the field, their continuity of play, their ball retention and their ability to score.

Once this comprehensive pilot study had been completed for rugby union, a similar strategy for association football was also developed.

3.3 Validity and Reliability of the Notation Systems

3.3.1 Overview

In order to ensure that the results obtained from the research instruments were accurate it was important to test the notation systems for validity and reliability. Whilst analysis may vary according to the tactical or technical components of a game, whatever form it takes it is essential that the analysis is accurate (Franks and Goodman, 1984).

No measurement is free from error or uncertainty. If any measurement is to have scientific application then it is necessary to quantify and understand any uncertainties that arise. In scientific terms, error is defined as the inevitable uncertainties that attend all measurements. They are unavoidable and the best that can be done is to keep them to a minimum.

There are two types of errors: random and systematic. Systematic errors occur when all the errors are in the same direction and are out of our control (as is the case, for example when a stop watch is running slowly). These errors cannot be discovered by statistical analysis. Random errors occur when experimental uncertainties can be revealed by repeating the measurements. Reason (1981), Hughes, Franks and Nagelkerke (1989), and Johnson and Franks (1991) amongst others have indicated how researchers can address the validity and reliability of systems.

3.3.2 Validity

As Reason (1981) has indicated "the issue of validity is of critical importance for inquiry within any research paradigm". Hughes, Franks and Nagelkerke (1989) have demonstrated the ways in which validity can be addressed in sport related research.

In one sense, validity relates to measurement and it refers to the extent to which an instrument measures what it purports to measure. Kazdin (1977) defined it as "the extent to which observations scored by an observer match those of a pre-determined standard for the same data". Reason (1981) argued that "the essential notion of a valid measure is that it is reaching out for some 'true measure' ". In another sense, validity relates to experimentation as discussed by Campbell and Stanley (1966). They consider whether experiments have internal and external validity and provide a detailed account of the threats to internal and external validity. They also indicate how neophyte researchers should go about minimising those threats. Rogers (cited in Reason, 1981) makes an excellent point about the validation of a system:

> it is a way of preventing me from deceiving myself in regard to my creatively formed subjective hunches which have developed out of the relationship between me and my material.

The hand and computer systems for this study were validated in a variety of ways. The focus group considered the face validity of the systems and agreed that what was proposed 'looked right' to a discriminating observer. The researcher had also worked with governing bodies for rugby football and association football and had established a convergent validity for measures of performance in real-time systems. That is, a number of measures which purported to measure the same thing all pointed in the same direction. The accuracy of the systems were also measured by comparing data from the hand and computer systems in a lapsed-time study. All these validation procedures did not yield any counter-intuitive or counter-predictive data for the measures themselves. Attempts were made to minimise any timing errors by regular checking of stopwatches and computer clocks.

In summary, determined efforts were made to validate the hand and computer systems. This validation process is distinguished from the issues of inter-observer and intra-observer reliability discussed in the next section.

3.3.3 Reliability

An individual will use skills learnt from experience, trial and improvement and interaction with more experienced colleagues to judge the reliability of an experiment. But however confident one is in the reliability of the results this subjective confidence will not be enough to qualify those results as a part of scientific knowledge. The results will have to stand up to further testing from colleagues.

The systematic observation within this study involves observing and recording of data. Systematic observation was defined by Darst, Mancini and Zakrajruk (1983) as:

> a trained person following stated guidelines and procedures to observe, record, and analyse interactions with the assurance that others viewing the same sequence of events would agree with his recorded data.

This reliability stresses the importance of consistency and refers to the ability of an observer to yield the same results when the tests are repeated. Observer agreement indicates the degree to which observers who view events agree in their recording, and a percentage of observer agreement is used as an indicator of observer reliability. This is calculated by dividing the number of agreements over the total number of agreements and disagreements. Agreements would be any aspect of the total observation for which both observers, or the same observer at any one time, both saw and heard the same behaviour and recorded it as such. The differences would be any omissions or differences in interpretations.

There are two types of observer agreement. Inter-observer agreement is a reliability measure between two observers. Intra-observer agreement measures reliability in terms of one observer who observes the same events on two or more occasions. For inter-observer tests both observers need independence but should start and end at exactly the same time to avoid any threats to validity. For intra-observer tests, the observer should perform the tests with a period of at least one week between observations. Sources of observer error could range from observer drift, which may be caused by boredom, to complexity of observation system, biases and even reactivity or cheating due to the fact that one knows that they are being tested (van der Mars, 1983). In more specific sporting tests such factors as state of arousal, nature of observational medium or focus of attention could affect accuracy. Johnson and Franks (1991) have provided a detailed example of the measurement of the reliability of a computer-aided systematic observation instrument.

It is clear that the need for accurate and reliable data is of paramount importance. Some of the errors that could occur in reliability tests which were stated by van der Mars (1983) can be overcome by allowing extensive periods of training for directing observations and reducing the number of critical features that should be observed.

House, House and Campbell (1981) discussed measures of inter-observer agreement. They identified seventeen measures of association for observer reliability (inter-observer agreement) and suggest that it is difficult to compare reliability measures since most use notational systems unique to the author and for the mathematically unsophisticated the practical consequences of different interpretations are not always apparent.

House et alia (1981) recommended that any attempt to calculate inter-observer agreement should take into account that:

1. Measures are based on fourfold concordance
2. The use of simple or complicated measures is a matter of judgement
3. Research reports should include data on individual agreements rather than on single agreement figure.
4. Any difficulties should not obscure the value and utility of observational procedures.

Correlation measures are frequently used to control for chance in observer agreement, particularly in sports science. Coolican (1994) recommended their use as a measurement of test-retest reliability. Nevill (1996) suggested, however, that in order to assess the agreements between two different tests or measurement methods it is not appropriate to use such measures since correlation coefficients are measurements of relationship not agreement. Atkinson (1996) stated:

> Poor repeatability of measurements can influence the results of a study in which repeated measurements of a particular variable are recorded over time.

Some measure of behaviour concordance should be used though and it is important to identify if there is a single best measure. Bland and Altman (1986) suggested the following steps in comparing agreement between two measurements.

1. A simple plot of one measurement against another.
2. A plot of the differences of the measurements against their mean. (A Bland and Altman plot)
3. Calculate the 95% limits of agreement (mean difference between test-retest plus or minus the difference between the test-retest scores multiplied by 1.96) and each sport scientist to use his own judgement to decide whether the interval is acceptably precise.
4. A t-test if required.

Pilot Studies: Testing the Notation Systems for Reliability

Both inter- and intra- observer reliability tests were carried out to measure the accuracy of the data collected. The methods used to test for reliability were:

1. Scott's Pi coefficient of reliability.
2. A measure of the proportion of agreements and disagreements.
3. Simple plots of each variable against the other observer or the other test.

There is no universally accepted minimum level of percentage agreement. Hartmann (1977) and Johnson and Bolstad (1973) suggested an 80-85% level particularly when using a complex observation system, rising to 90% when measuring only one variable. Intra-observer reliability tests were performed on the real-time hand and computer notation systems for association football and rugby union. The association football system was tested for reliability in the Denmark v Germany match, the final of the European Championships in Sweden in 1992, and the Wales v South Africa international in 1994 was chosen to test the rugby union systems.

The results of the Scott's Pi Coefficient of Reliability and the measure of proportion of agreements and disagreements for the pilot studies undertaken are shown here. The plots for one test are also illustrated. For the remaining plots, the calculations for the tests and the comparison of test results see Appendix B.

Table 5: Reliability test results

Intra-observer reliability test of the association football hand-notation system

1.	Using Scott's Pi Coefficient of Reliability	= **0.9091**
2.	Using Agreements/Disagreements	= **92.3636**

Intra-observer reliability test of the rugby union hand-notation system

1.	Using Scott's Pi Coefficient of Reliability	= **0.8720**
2.	Using Agreements/Disagreements	= **90.9574**

Intra-observer reliability test of the association football computer-notation system

1.	Using Scott's Pi Coefficient of Reliability	= **0.9804**
2.	Using Agreements/Disagreements	= **97.8564**

Intra-observer reliability test of the rugby union computer-notation system

1.	Using Scott's Pi Coefficient of Reliability	= **0.9938**
2.	Using Agreements/Disagreements	= **95.6432**

Inter-observer reliability test of the association football hand-notation system

1.	Using Scott's Pi Coefficient of Reliability	= **0.9406**
2.	Using Agreements/Disagreements	= **94.5876**

Inter-observer reliability test of the association football computer-notation system

1.	Using Scott's Pi Coefficient of Reliability	= **0.9710**
2.	Using Agreements/Disagreements	= **96.6292**

Inter-observer reliability test of the rugby union computer-notation system

1.	Using Scott's Pi Coefficient of Reliability	= **0.9097**
2.	Using Agreements/Disagreements	= **92.5156**

An inter-reliability test of the rugby union hand-notation system was not undertaken due to the difficulty the second observer experienced in replicating the analysis. However, each match analysed was also analysed by the computer programme. The difficulties encountered by the second observer highlight the problems inherent in attempting to ascertain the reliability of a

Plots for the inter-reliability test of the rugby union computer system

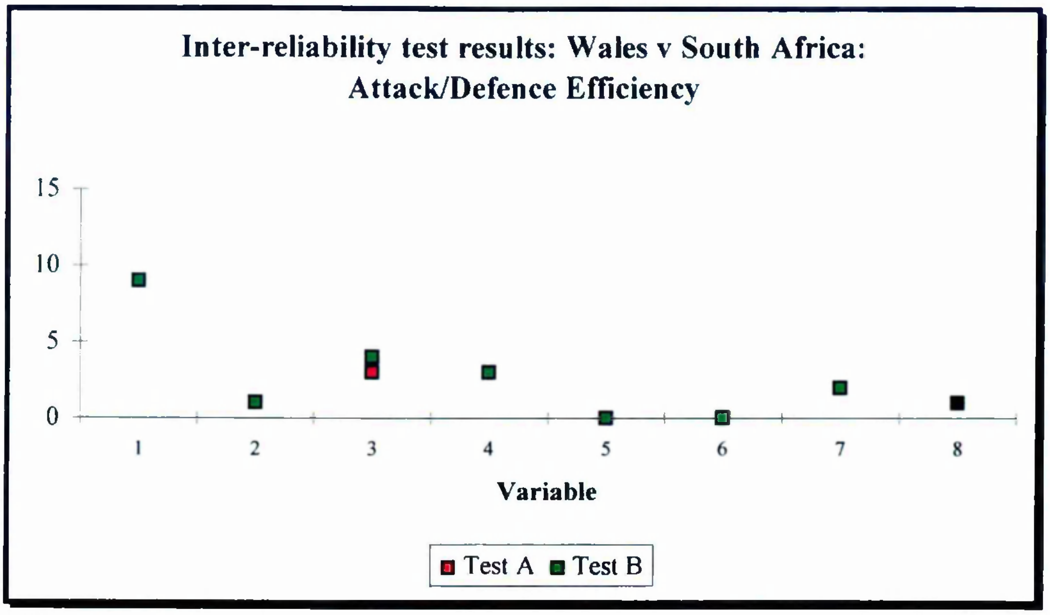

Figure 1:Inter-reliability plots of the rugby union computer system: Attack/defence efficiency

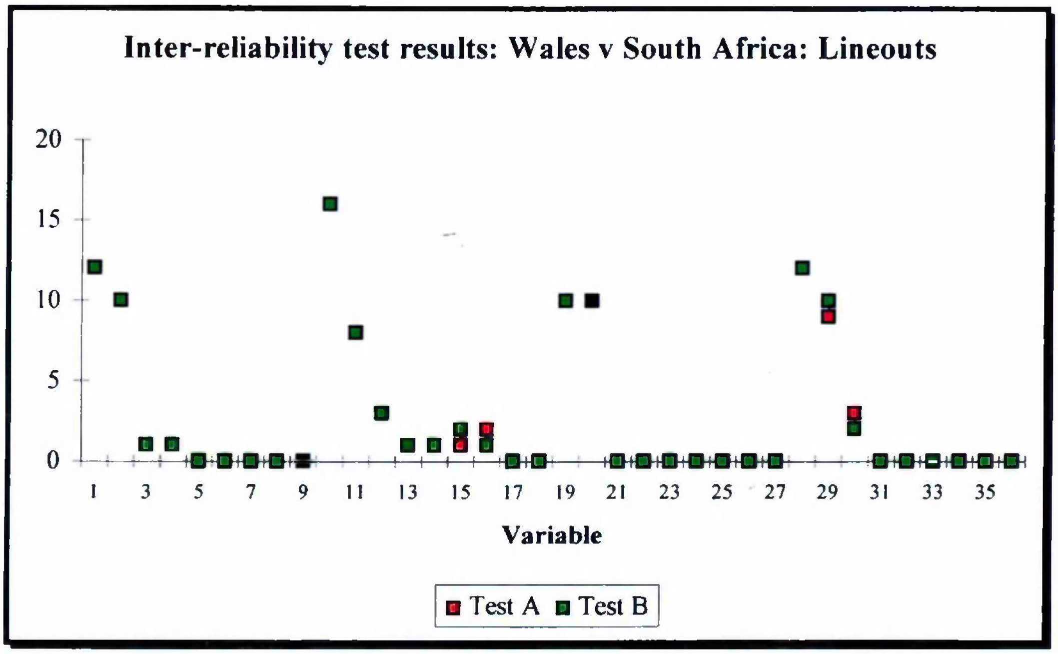

Figure 2: Inter-reliability plots of the rugby union computer system: Lineouts

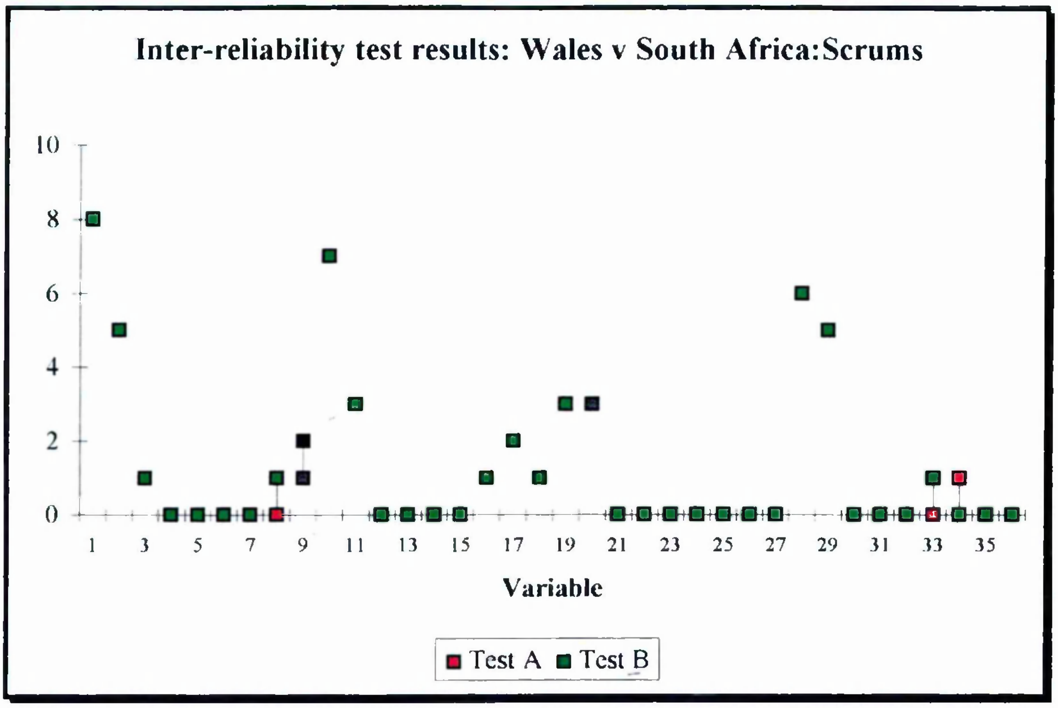

Figure 3: Inter-reliability plots of the rugby union computer system: Scrums

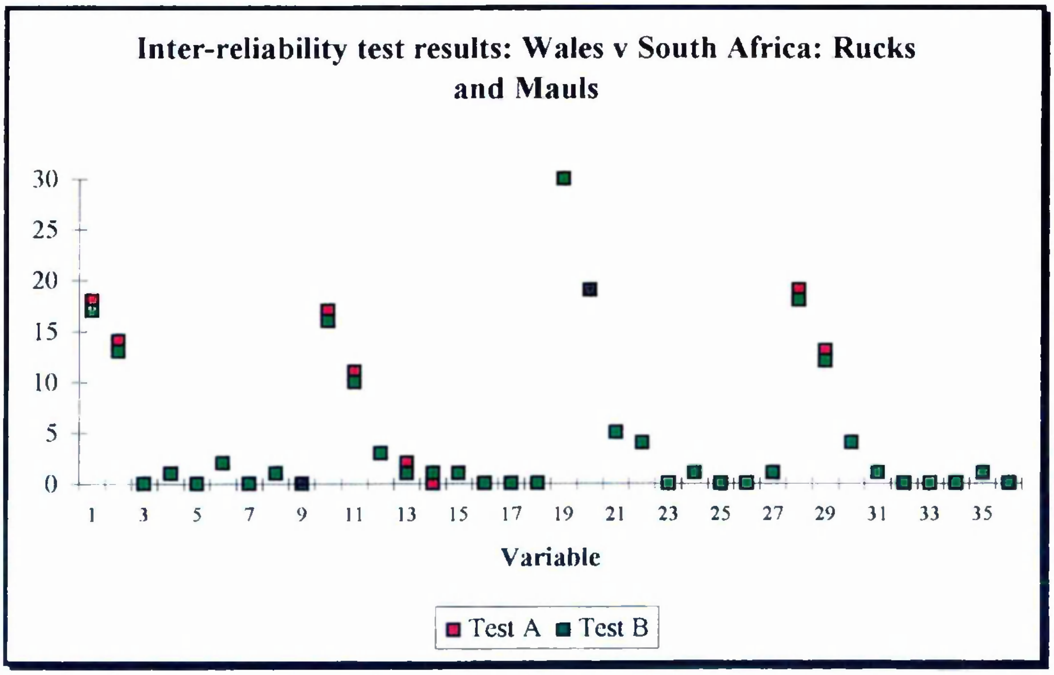

Figure 4: Inter-reliability plots of the rugby union computer system: Rucks and mauls

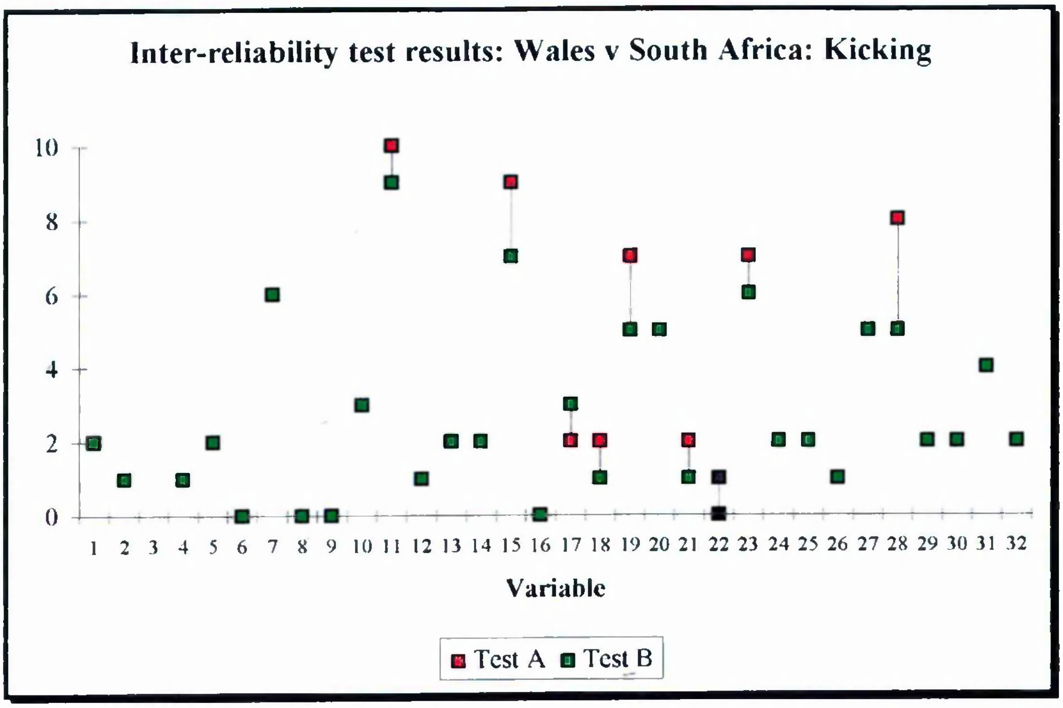

Figure 5: Inter-reliability plots of the rugby union computer system: Kicking

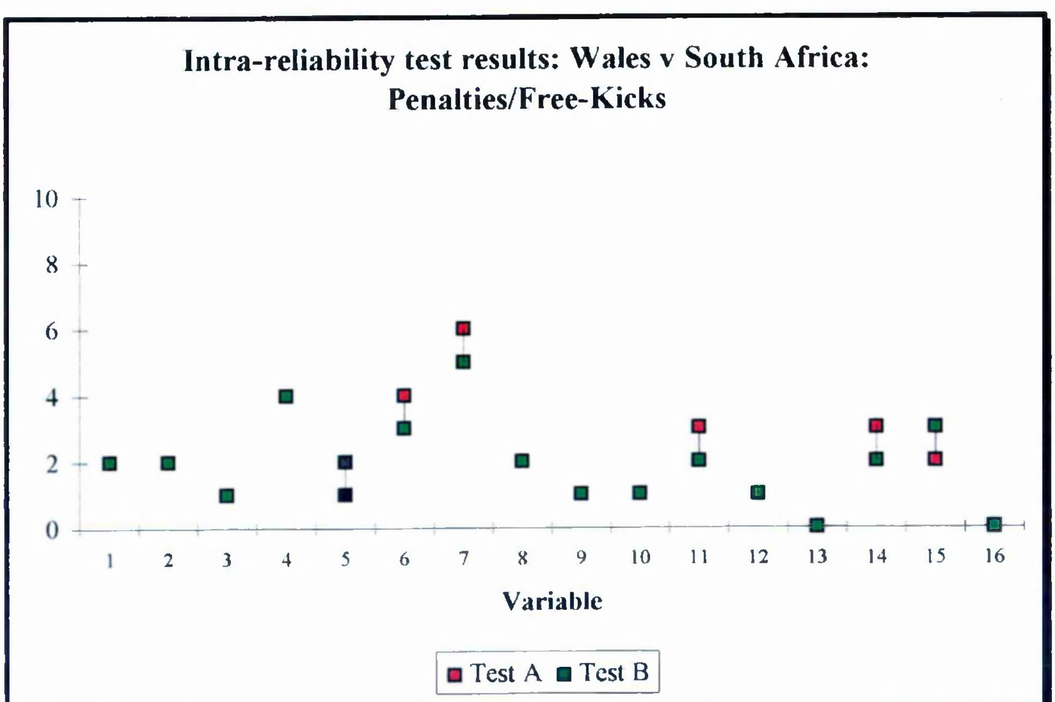

Figure 6: Inter-reliability plots of the rugby union computer system: Penalties/free kicks

3.4 Data Collection

The data in this study were collected using real-time notation systems. Some additional information was collected with lapsed-time analysis. The requirement for any model to use data that could be collected in real-time was considered to be a prerequisite of the study. Data were collected in two invasive team games: rugby union and association football. At an early stage in the research it was decided to concentrate solely on senior international fixtures. During the period of study the Rugby World Cup and Soccer World Cup were to be held and each year of the research a Five Nations' tournament was held in rugby union. which brought together the five best international teams in Europe. To complement the Five Nations' tournament it was decided to collect data from the European Soccer Championships which were held in 1996.

The following matches were analysed:

Table 6: Association football matches analysed

Association Football	Tournament	Venue	Notation	Number
World Cup	USA '94	America	Real-time, hand	33
European Championship	EURO '96	England	Real-time, computer	20

Table 7: Rugby union matches analysed

Rugby Union	Name	Venue	Notation	Number
World Cup	RWC 95	S Africa	Real-time, hand	32
World Cup	RWC 95	S Africa	Real-time, computer	32
Five Nations	FN 1995	/	Real-time, hand	10
Five Nations	FN 1995	/	Lapsed-time, computer	10
Five Nations	FN 1996	/	Real-time, computer	10

In total 53 association football matches were analysed, 33 by real-time hand notation from the World Cup 1994 and 20 by real-time computer notation from the European Championships 1996. In total 52 rugby union matches were analysed, 32 by real-time computer notation from the World Cup 1995 and 10 matches from the Five Nations' Championships of 1995 and 1996. The World Cup matches were also analysed in real-time by hand notation as a back-up source since the tournament was the first major use made of the computer system. The 1995 Five Nations' Championship was analysed by real-time hand notation and by lapsed-time hand-notation to provide individual details for one of the investigations. The 1996 Five Nations' tournament was analysed by the real-time computer system.

3.5 Statistical Procedures

The literature on the analysis of performance makes reference to a range of statistical procedures for the treatment of data. A number of studies made use of a parametric test, Pearson's Product-Moment Correlation. This was used as a preliminary test in this study to investigate whether there were any significant variables associated with winning performance in invasive team games. The test produced some surprising and counter-intuitive results. To remedy these difficulties, advice was sought from experienced statisticians who suggested the use of a non-parametric test, namely, Spearman's Rank Correlation. This test proved to be extremely helpful in exploring winning (and losing) performance. In hindsight it would have been much more effective to have used Spearman's Rank Correlation from the outset for data that were not normally distributed. A chi-square test was carried out on the time interval data to discover whether there were any significant differences between winners and losers.

The results of both statistical tests are presented in Chapter Four. Statistical tables for the significance levels for each of the tests are included in Appendix A.

3.6 Summary

This chapter has presented details of the research instruments used in the study and reports the efforts made to ascertain the validity and reliability of those instruments. The data population for the study involved a total of 105 senior international fixtures (52 rugby union games and 53 association football games). Brief mention was made of the statistical procedures used. The chapter was written with the explicit intention of providing a transparent account of the methodology used so that subsequent researchers could replicate the study or further develop the methods identified.

In the next chapter the data collected with the methods identified here are presented and discussed.

Chapter 4: Presentation and Discussion of Results

4.1 Overview

The aims of the research (see **1.1**) and four research questions (see **1.4**) were identified in Chapter One. The presentation and discussion of results here are structured by those aims and research questions. In the quest for a model of winning performance in invasive games a variety of investigations have been undertaken over a four-year period. As a result of this time scale, the investigations have had a developmental tenor. Their applicability varied within a sport and between sports. Results from rugby union investigations are presented in **4.2** and from association football in **4.3**. In both sports, these results are discussed in terms of:

1. Game Content
2. Match Officials
3. Home-Ground Advantage
4. First Score
5. High Performance Ratings
6. Winning Range
7. The Champions
8. Possession Count
9. Yes/No Challenge
10. Spearman's Rank Correlation Coefficient
11. Performance Profile
12. Game Rhythm
13. Time Intervals

In addition, two further investigations were conducted for rugby union:

14. The Chaotic Pattern
15. Individual Member Competence and Team Productivity

4.2 Rugby Union

4.2.1 Game Content

The 1996 Five Nations' tournament (Table 8) produced an average of nearly 27 minutes ball in play time per match, and within this time a total of 30 tries were scored and 355 points. Match time figures vary from a bare 15 seconds of injury time to a maximum of 6 minutes 54 seconds, and ball in play figures vary from a low 23 minutes and 56 seconds to a relatively high figure of 29 minutes and 35 seconds. The number of lineouts still exceed the total number of scrums in a match but the difference between these figures is reducing. The recycled possessions provide the greatest variance in the figures ranging from 51 to 99.

Table 8: Global figures for the 1996 Five Nations' Tournament

Variable	Total	Minimum	Maximum	Mean
Match time	837m 01s	80m 15s	86m 54s	83m 42s
Ball in Play	269m 35s	23m 56s	29m 35s	26m 57s
Lineouts	364	27	45	36
Scrums	301	21	38	30
Penalties/FK	277	19	33	28
Rucks/Mauls	762	51	99	76
Kicks	925	81	101	93
Points	355	26	55	36
Tries	30	0	8	3

In the individual match frequencies there is little pattern within the figures (see Table 9). Although France are involved in matches with a low number of kicks (81) on two occasions in their match against England there were over one hundred kicks. Scotland's matches against Ireland, France and England had a high number of activity cycles (120, 116, 117 respectively) but against Wales there were only 103 cycles in the match. No country was consistently involved in either high scoring or low scoring matches although three of the English matches only had 1 try or less.

Table 9: Individual match frequencies for the 1996 Five Nations' Tournament

Match	Points (Tries)	Match Time	Ball in Play	Activity Cycles	Line outs	Scrums	Rucks Mauls	Pens FK	Kicks
France v England	27 (0)	81m 34s	26m 45s	107	29	38	73	19	101
Ireland v Scotland	26 (3)	85m 24s	29m 35s	120	39	38	99	30	85
England v Wales	36 (4)	86m 54s	26m 41s	101	27	29	69	30	90
Scotland v France	33 (3)	82m 16s	27m 09s	116	39	31	61	22	93
France v Ireland	55 (8)	80m 15s	28m 41s	100	28	32	92	29	81
Wales v Scotland	30 (2)	83m 53s	27m 58s	103	38	25	79	26	98
Scotland v England	27 (0)	82m 12s	25m 19s	117	45	21	70	33	101
Ireland v Wales	47 (6)	83m 26s	27m 02s	112	39	31	51	32	98
Wales v France	31 (3)	84m 34s	23m 56s	112	40	33	77	31	81
England v Ireland	43 (1)	86m 33s	28m 12s	107	40	23	91	25	97

The final stages of the 1995 Rugby World Cup involved over 45 hours of international rugby. The thirty two matches played produced 1730 points including 187 tries and in over 861 minutes of live play there were in excess of two thousand rucks or maul possessions and nearly twice as many passes as there were kicks.

Table 10: Global figures for the 1995 Rugby World Cup

Variable	Total	Minimum	Maximum	Mean
Match time	2713m 22s	80m 05s	92m 32s	84m 48s
Ball in Play	854m 51s	21m 50s	31m 56s	26m 43s
Lineouts	1180	23	52	37
Scrums	870	15	40	27
Penalties/FK	796	13	39	25
Rucks/Mauls	2216	47	97	69
Kicks	3081	73	133	96
Points	1721	18	162	54
Tries	187	0	23	6

The total figures for the World Cup are of interest in that they give a general view of what happened in the tournament irrespective of the countries playing, officials and the conditions but to be of any greater use there is a need to look at what happened in an average match, or in one of the most expansive matches or in one of the close, tight matches. By looking at individual matches it is evident that within these areas of game content there are large differences from match to match. The actual content of the matches is shown in Table 11. One might expect the ball in play time to be similar for each match but there are large differences: a 10 minute difference between the largest ball in play time and the smallest.

Table 11: Individual match frequencies for the 1995 Rugby World Cup

Match	Points (Tries)	Match Time	Ball in Play	Activity Cycles	Line outs	Scrums	Rucks Mauls	Pens FK	Kicks
Australia v S Africa	45 (4)	81:16	29:13	112	32	29	76	14	109
Scotland v I Coast	89 (13)	86:23	29:07	91	37	21	66	24	89
France v Tonga	48 (5)	79:56	22:37	98	33	22	75	20	86
Canada v Romania	37 (3)	83:42	25:49	116	45	34	73	25	96
Wales v Japan	67 (9)	88:11	27:04	123	43	29	95	32	77
W Samoa v Italy	60 (8)	82:00	26:14	114	29	29	66	33	87
England v Argentina	42 (2)	82:03	27:22	122	42	31	83	28	112
N Zealand v Ireland	62 (8)	84:57	22:29	107	40	21	55	25	104
W Samoa v Argentina	58 (5)	84:36	27:30	112	26	40	69	30	95
S Africa v Romania	29 (3)	86:06	27:45	110	49	21	69	23	111
France v I Coast	72 (9)	92:34	25:59	108	31	17	69	39	91
Scotland v Tonga	46 (4)	84:48	23:54	102	36	26	67	25	92
Australia v Canada	38 (4)	86:52	31:49	114	25	37	95	39	79
Ireland v Japan	78 (11)	83:22	27:28	101	28	33	112	20	79
England v Italy	47 (4)	83:17	27:29	134	52	33	62	24	115
N Zealand v Wales	43 (3)	83:16	24:16	99	36	21	61	23	97
Tonga v I Coast	40 (5)	88:12	21:51	103	33	28	57	30	73
Australia v Romania	45 (6)	86:03	27:09	95	48	21	90	12	95
Scotland v France	41 (2)	88:37	26:33	116	44	27	82	21	100
S Africa v Canada	20 (2)	85:34	30:37	114	42	36	86	28	85
Argentina v Italy	56 (7)	82:59	30:29	121	43	25	85	31	130
N Zealand v Japan	162 (23)	80:48	27:14	90	23	15	72	21	91
Ireland v Wales	47 (5)	88:03	25:45	112	44	29	60	16	107
England v W Samoa	66 (7)	85:20	25:34	105	42	18	83	31	92
France v Ireland	48 (2)	86:35	24:24	110	33	34	74	23	91
S Africa v W Samoa	56 (8)	83:55	26:33	92	30	18	71	26	87
England v Australia	47 (2)	86:57	29:13	115	33	31	73	25	132
N Zealand v Scotland	78 (9)	84:15	25:02	92	27	16	60	27	104
France v S Africa	34 (1)	83:01	25:44	128	44	31	69	24	121
England v N Zealand	74 (10)	83:30	26:06	102	23	29	67	24	94
France v England	28 (2)	85:48	28:46	108	41	34	98	17	84
S Africa v N Zealand	18 (0)	82:05	26:45	117	50	30	60	17	105

In one of the matches, Tonga v Ivory Coast, the ball was in play for only 26% of the running clock. At tne other end of the scale, the Australia v Canada match had 37% ball in play. This match also had the highest absolute figure for ball in play of 31 minutes and 56 seconds. Only two other matches in the tournament, Canada v South Africa with a 30 minutes 48 seconds ball in play time and Argentina v Italy with 30 minutes 8 seconds, exceeded the 30 minute barrier. The Australia v Canada match was, statistically, one of the most incredible matches of the tournament. As well as having the highest ball in play time it had the most number of passes, the greatest number of scrums, the largest penalty and free-kicks figure, the most tackles and the second largest number of second phase possessions. Conversely, it was one of the matches with the fewest number of lineouts and the fewest number of kicks in open play. There was only one match in the tournament which had more kicks than passes and not surprisingly this was the semi-final between France and South Africa in the rain and wind of Durban. A significant point however is the pass to kick comparison between winning and losing sides. In the early stages of the tournament there was no large correlation between the passing patterns of sides and whether they won or lost the match but in the final eight matches, that is the knock-out stages, the losing side passed the ball more than the winners. The two exceptions here were the English and South African matches against the French. This is not a counter-predictive research outcome. The French consistently pass the ball more than the opposition regardless of whether they are winning and losing.

The set-piece and their relative importance in the game has changed since the major law changes of 1992. There has been a gradual decrease in the number of scrums while the lineouts have grown in number. On average there were 10 more lineouts than scrums in each match of the World Cup. This again varied according to the match, that is, the countries' relative strengths and the type of game played. For instance, Canada's three matches had a high number of scrums because they tended to try and keep the ball infield. This inevitably led to a greater number of phases commencing with the scrum due to ball not emerging from the high number of rucks and mauls set-up and a higher proportion of handling errors. However, it was only in four of the matches that the total number of scrums exceeded the total number of lineouts: Western Samoa v Argentina; Australia v Canada; Ireland v Japan; and France v Ireland. The lowest number of set-pieces in one match was the New Zealand v Japan match with only 38 (23 lineouts and 15 scrums), while the highest was the England v Italy match (51 lineouts and 36 scrums).

This variability is evident throughout every aspect of game content. The second phase possessions reached a maximum of close on one hundred, again the Canadian matches are in evidence here, as well as the Japanese. The minimum number of ruck and maul possessions was below 50 per match. Of growing importance in the modern game is the number of turnovers at ruck or maul that a side concedes. If one refers to a turnover as a ruck or maul which yields either possession or a scrum feed to the opposition, then the figures show that, in the World Cup, the side which yielded the fewer number of turnovers, in relation to the number of rucks and mauls they set-up, won the match 72% of the time (in 23 of the 32 matches). One of the most encouraging factors though is the number of points scored per match. The average of 54 points not only reflected the increasing accuracy of the world's goal-kickers but also the substantial number of tries scored. The generally dry, sunny conditions and hard, fast grounds meant that at least five tries were scored in over 17 of the matches and it was only in one of the 32 matches, the final, that no try was scored.

England were involved in 4 matches with a very high number of kicks. New Zealand were involved in high try-scoring matches while France, surprisingly, are involved in low try-scoring matches. The French were involved in 4 matches with only two or less tries. New Zealand's matches often had less than 100 activity cycles.

4.2.2 Match Officials

In a sport such as rugby union, with a large number of laws, the match officials, and the referee in particular, have a major influence on the game. A common problem encountered is the difference in interpretation between referees from each country. There seems to be a particular difference in interpretation between countries in the Northern and Southern hemispheres. For this reason it is important that the data collected for each match are discussed with reference to the match officials.

It is impossible to draw any significant conclusions from a data set of only ten matches such as the 1996 Five Nations' Tournament. However, there was no apparent pattern in terms of the team winning and the country of origin of officials: seven of the matches were won by home sides and of the three won by away sides, all were officiated by different countries' officials. It was apparent that when the officials refereed the country for the second time, on four of the five occasions that team lost. The exceptions were England who won both matches under Scottish officials. This raises a possible issue of a team of officials being familiar with one country's play having previously been in charge of them. Although no conclusions can be drawn from these results some issues are raised which suggest that the match officials involved could have a bearing on the end result of a match, for instance familiarity with styles of play, non English-speaking referees (French) not being in charge of one countries' matches, or one country's officials enabling a faster, more continuous game than another country's officials. These are issues which could be examined further on larger data sets such as World Cups.

Table 12: Match officials for the 1996 Five Nations' Tournament

Match	Referee	Touch Judge 1	Touch Judge 2
France v England	D. McHugh (Ire)	B. Stirling (Ire)	B. Smith (Ire)
Ireland v Scotland	B. Campsall (Eng)	T. Spreadbury (Eng)	S. Piercy (Eng)
England v Wales	K. McCartney (Scot)	R. Megson (Sco)	E. Murray (Scot)
Scotland v France	C. Thomas (Wal)	D. Bevan (Wal)	G. Simmonds (Wal)
France v Ireland	E. Morrison (Eng)	S. Lander (Eng)	J. Pearson (Eng)
Wales v Scotland	J. Dume (Fra)	P. Thomas (Fra)	D. Gillet (Fra)
Scotland v England	D. Bevan (Wal)	G. Simmonds (Wales)	C. Thomas (Wal)
Ireland v Wales	D. Mene (Fra)	P. Thomas (Fra)	R. Duhau (Fra)
Wales v France	B. Stirling (Ire)	G. Black (Ire)	B. Smith (Ire)
England v Ireland	E. Murray (Scot)	K. McCartney (Scot)	C. Muir (Scot)

In the 32 matches in the 1995 Rugby World Cup, 20 were contested between one team from the Northern and one team from the Southern Hemispheres. Eleven of these were won by Southern Hemisphere sides, nine by Northern Hemisphere sides. Of the eleven won by the Southern Hemisphere teams eight were refereed by a Northern Hemisphere official; of the nine won by the Northern hemisphere sides four were refereed by Southern Hemisphere officials. The champions, South Africa, played and won six matches: all of which were refereed by Northern Hemisphere officials. The runners up, New Zealand, were refereed in five of their six matches by Northern Hemisphere officials.

There might be no reason for this other than that these were the best two teams in the tournament but it suggests that subconsciously referees may be more severe on teams from their own Hemisphere, possibly because they come into contact with the players more often or are used to refereeing the particular style of play of that team. Three referees were in charge of three matches. Bevan refereed South Africa twice and they won on both occasions, but Bishop refereed England twice and Morrison refereed New Zealand twice (in both cases the team who won their first match, lost the second). The only other referee who refereed the same country was Hilditch (Ireland) who was in charge of two English matches. They again won the first match and lost the second. This raises the issue of referees being familiar with teams' playing styles, especially over such a small time span. The officials are listed in Table 13.

Seven matches were officiated by non English-speaking referees or referees whose first language was not English. The issue about the language barrier is the number of English-speaking teams that win when the referee is non-English speaking and vice versa. In the five matches involving one English speaking team and one non-English speaking team and a non-English speaking referee the English speaking team won each time. This might also be due to the fact that the English speaking teams are traditionally stronger and would be expected to win in any case. There were 12 matches involving one English speaking team and one non-English speaking team and an English speaking referee, and the English speaking team won 9 of the matches. The other three were won by the French. There does seem to be issues to address here especially with regards to referees' familiarity with teams having an affect on the end result and the language barrier on the penalties awarded during matches.

Table 13: Match Officials for the 1995 Rugby World Cup

Match	Referee	Touch Judge 1	Touch Judge 2
Australia v S Africa	D. Bevan (Wales)	C. Thomas (Wales)	S. Hilditch (Ireland)
Scotland v I Coast	F. Vito (W Samoa)	I. Rogers (S Africa)	E. Tonga (Tonga)
France v Tonga	S. Lander (England)	E. Morrison (Eng)	N. Saito (Japan)
Canada v Romania	C. Hawke (N Zealand)	D. Bishop (NZ)	D. Reordan (USA)
Wales v Japan	E. Sklar (Argentina)	S. Hilditch (Ireland)	D. McHugh (Ire)
W Samoa v Italy	J. Dume (France)	P. Robin (France)	D. McHugh (Ire)
England v Argentina	J. Fleming (Scotland)	K. McCartney (Scot)	H. Moon Soo (Kor)
N Zealand v Ireland	W. Erickson (Aus)	B. Leask (Australia)	G. Gadjovich (Can)
W Samoa v Argentina	D. Bishop (N Zealand)	C. Hawke (NZ)	J. Dume (France)
S Africa v Romania	K. McCartney (Scot)	J. Fleming (Scotland)	F. Vito (W Samoa)
France v I Coast	H. Moon Soo (Korea)	D. Bevan (Wales)	G. Gadjovich (Can)
Scotland v Tonga	B. Leask (Australia)	N. Saito (Japan)	W. Erickson (Aus)
Australia v Canada	P. Robin (France)	J. Dume (France)	D. Reordan (USA)
Ireland v Japan	S. Neethling (S Africa)	I. Rogers (S Africa)	E. Tonga (Tonga)
England v Italy	S. Hilditch (Ireland)	D. McHugh (Ireland)	N. Chichiu (Rom)
N Zealand v Wales	E. Morrison (England)	S. Lander (England)	B. Leask (Australia)
Tonga v I Coast	D. Reordan (USA)	K. McCartney (Scot)	E. Sklar (Argentina)
Australia v Romania	N. Saito (Japan)	D. Bishop (NZ)	C. Giacomel (Italy)
Scotland v France	W. Erickson (Australia)	B. Leask (Australia)	S. Neethling (SA)
S Africa v Canada	D. McHugh (Ireland)	S. Hilditch (Ireland)	S. Lander (England)
Argentina v Italy	C. Thomas (Wales)	D. Bevan (Wales)	K. Seraphin (ICoast)
N Zealand v Japan	G. Gadjovich (Canada)	E. Morrison (Eng)	N. Chichiu (Rom)
Ireland v Wales	I. Rogers (S Africa)	S. Neethling (S Africa)	E. Sklar (Argentina)
England v W Samoa	P. Robin (France)	J. Dume (France)	J. Fleming (Scot)
France v Ireland	E. Morrison (England)	S. Lander (England)	I. Rogers (S Africa)
S Africa v W Samoa	J. Fleming (Scotland)	P. Robin (France)	J. Dume (France)
England v Australia	D. Bishop (N Zealand)	C. Hawke (N Zealand)	S. Hilditch (Ireland)
N Zealand v Scotland	D. Bevan (Wales)	C. Thomas (Wales)	W. Erickson (Aus)
France v S Africa	D. Bevan (Wales)	C. Thomas (Wales)	W. Erickson (Aus)
England v N Zealand	S. Hilditch (Ireland)	J. Dume (France)	S. Neethling (SA)
France v England	D. Bishop (N Zealand)	C. Hawke (NZ)	W. Erickson (Aus)
S Africa v N Zealand	E. Morrison (England)	D. Bevan (Wales)	J. Dume (France)

4.2.3 Home-Ground Advantage

In **1.3.2** the literature regarding home-ground advantage was discussed. In the Five Nations' Championship teams play two home games and two away games. They alternate between home and away. There is no neutral venue used and thus the possibility that home ground advantage has an effect on the end result must be examined.

The Five Nations is a tournament that is played over ten matches on five Saturdays in an eight week period. On each of the Saturday's there are two matches involving four of the sides with one side not playing. The format is one of each team playing each other once and each team plays a total of four matches. The two matches which are played at home then become the matches that the team plays away from home the following year.

In the 1996 Five Nations' tournament, the home-ground advantage was available in all matches. The team playing at home won in seven of the ten matches. It would seem fair to assume that the home sides' knowledge of the home conditions plus the effect of the crowd size, density and support was invaluable to them. The variables collected were ones that may exhibit the possible effect that home-ground advantage may have on a result. The variables illustrate pressure by the home team on the opposition, a factor which is often influenced by such things as knowledge of conditions and crowd support. Table 14 shows the data for the home team in each match.

Seven of the matches resulted in a home win. Overall the home side scored 207 points (58%) as opposed to conceding 148. The home side had greater territorial dominance in eight of the matches. In the two matches that they failed to secure a longer period of time in the opposition half than the away side then they lost. A similar pattern shows through in the number of times that the home side had entries into the opposition's 22 metre area. The home side had a greater number in nine of the matches.

Table 14: Home Team's Data for the 1996 Five Nations' Tournament

Match	Home Win	Territorial Dominance	Times in Opp 22m	Time in Possession	Penalties Awarded
France v England	Yes (56%)	44m 22s (54%)	8 (53%)	11m 11s (56%)	12 (63%)
Ireland v Scotland	No (38%)	38m 00s (45%)	16 (59%)	13m 29s (55%)	17 (57%)
England v Wales	Yes (58%)	51m 02s (59%)	18 (67%)	11m 24s (55%)	19 (63%)
Scotland v France	Yes (58%)	49m 06s (60%)	15 (60%)	12m 24s (56%)	14 (64%)
France v Ireland	Yes (82%)	51m 19s (64%)	17 (68%)	13m 00s (55%)	10 (34%)
Wales v Scotland	No (47%)	48m 22s (58%)	13 (72%)	9m 26s (42%)	11 (42%)
Scotland v England	No (33%)	29m 22s (36%)	4 (33%)	9m 28s (49%)	17 (53%)
Ireland v Wales	Yes (64%)	48m 25s (58%)	20 (65%)	11m 41s (53%)	21 (64%)
Wales v France	Yes (52%)	43m 02s (51%)	12 (57%)	10m 29s (54%)	20 (65%)
England v Ireland	Yes (65%)	56m 15s (65%)	15 (83%)	13m 46s (62%)	15 (60%)

Another indicator of sustained pressure is the time that the team can keep control the ball. This is shown in the time in possession figures, with the percentage figure indicating their share as opposed to the opposition (that is, only ball in play time excluding ball in air is considered). Again the home side has overall control of the ball more than the away side in eight of the matches, with the other two resulting in home defeats. The number of penalties is a further indicator of pressure exerted on the opposition resulting in penalties conceded. It may also indicate the pressure exerted on the referee by overwhelming home support. The home side are awarded more penalties on eight occasions. This time however a home side that does win does conceded more penalties. This is the France v Ireland match which was won by France by 45 points to 10, and suggests a possible leniency away from the home side and towards the away side when such an advantage is held by the home side.

Although the data set is small there seems to be clear indications that home-ground advantage is a key factor in the end result. The home side also enjoys dominance in pressure variables that are associated with home-ground advantage and all these factors combined together must have a bearing on home victories. The data clearly show a need to look at more home/away fixtures and also suggest that there is enough of an advantage that such data should be examined separately from tournaments like the World Cup where only one side out of the sixteen have home-ground advantage.

If there is such an advantage, the benefit of playing a World Cup tournament at home is significant. The Rugby World Cup is a tournament which is held in one country over a period of one month. In the 1991 Rugby World Cup held in the United Kingdom and France there were five sides - England, France, Ireland, Scotland and Wales - who had the benefit of home advantage in their group matches.

In the 1995 Rugby World Cup the home-field advantage applied to only one side, South Africa. They won all six matches (beating New Zealand in extra-time in the final). It would seem fair to assume that their knowledge of the home conditions plus the effect of the crowd size, density and support was invaluable to them.

Table 15: Home Team's Data for the 1995 Rugby World Cup

Match	Home Win	Territorial Dominance	Times in Opp 22m	Time in Possession	Penalties Awarded
South Africa v Australia	Yes (60%)	44m 54s (55%)	16 (64%)	10m 02s (45%)	8 (57%)
South Africa v Romania	Yes (72%)	52m 53s (61%)	23 (74%)	12m 52s (62%)	12 (52%)
South Africa v Canada	Yes (100%)	47m 36s (56%)	18 (67%)	9m 22s (37%)	10 (36%)
South Africa v Western Samoa	Yes (75%)	50m 59s (61%)	17 (63%)	10m 56s (51%)	19 (73%)
South Africa v France	Yes (56%)	42m 33s (51%)	8 (40%)	9m 08s (48%)	10 (42%)
South Africa v New Zealand	Draw (50%)	43m 40s (53%)	13 (52%)	9m 25s (41%)	11 (65%)

Table 15 shows the data for South Africa (the home team) in each match. Six of the matches resulted in a home win for South Africa although one match did end in a draw after normal time. Overall the home side scored 138 points (68%) as opposed to conceding 64. The home side had greater territorial dominance in all six of the matches. A similar pattern shows through in the number of times that the home side had entries into the opposition 22 metre area. The home side had a greater number in five of the matches. In the one when they had fewer number of entries their territorial dominance was only marginally better (51%) than the away side.

The time in possession figures, with the percentage figure indicating their share as opposed to the opposition, (that is, only ball in play time excluding ball in air is considered) shows the home side only has control of the ball more than the opposition in two matches. The number of penalties is a further indicator of pressure exerted on the opposition and of the pressure exerted on the referee by overwhelming home support. Once more the home side are awarded more penalties on four occasions. This time however a home side that does win do concede more penalties. Although the data set is small there seems to be clear indications that home-ground advantage is a key factor in the end result. The home side also enjoys dominance in pressure variables that are associated with home-ground advantage and all these factors combined together must have a bearing on home victories.

In the pool matches, each of the teams played two matches at the same venue. It may be significant that the winners of three of the four pools - South Africa, England and New Zealand played their first two matches at the same venue. This allowed them to set up base prior to the World Cup at their respective ‘home’ grounds and acclimatise to the particular environments while their opponents were made to travel after their first matches.

To conclude with the observation that the tournament winners were the host nation and the only side to have home-field advantage would appear to be as important an indicator as anything that home-ground advantage is a key to winning performance. It also continues the trend of previous rugby world cups. In 1987, New Zealand the host nation won the tournament and four years later England, one of the hosts, lost narrowly in the final.

4.2.4 The First Score

In all team games much emphasis is placed on a team starting off strongly and scoring early on in the contest. Ichiguchi (1981) looked at the significance of the first successful throw in wrestling leading to that wrestler winning the contest but there has not been much research in invasive team games.

The 1996 Five Nations' tournament was analysed in detail and one of the aspects investigated at was the first team to score. This was sub-divided into whether the team scored a goal (7-points), a try (5-points) or a penalty or dropped-goal (3-points), and whether the mode of scoring had any bearing on the final outcome of the match. The research also looked into whether the team that was in the lead at half-time won the match. The team that scored the first goal (try and conversion - 7 points) won the match on 5 out of 7 occasions. The other three matches did not have a goal scored. The team that scored the first try (5 points) won the match on 7 out of 8 occasions. The other two matches did not have a try scored. The team that scored the first 3 points (penalty or dropped-goal) won the match on 5 of 10 occasions. The team that scored first, irrespective of what mode of scoring, won the match on 7 out of 10 occasions. In addition, the team that was in the lead at half time won the match on 7 of 9 occasions. In the other match the scores were level at half-time. In summary, the probabilities are as follows:

Probability (Team scoring first goal wins)	=	5/7
Probability (Team scoring first try wins)	=	7/8
Probability (Team scoring first 3 points wins)	=	1/2
Probability (Team scoring first wins)	=	7/10

Probability (Team leading at half-time wins)	=	7/9
Probability (Team kicking-off scores first)	=	7/10
Probability (Team kicking-off scores first and wins)	=	1/2

Thus, the probability that a team wins the match if:

They score first and are leading at half-time	=	7/16
They kick-off, score first and are leading at half-time	=	4/10
They score first goal	=	5/14
They score first try	=	7/16
They score first 3 points	=	1/4
They score first	=	7/20
They are leading at half-time	=	7/18

The 1995 Rugby World Cup was investigated with regard to the first team to score. The same protocol was used as with the 1996 Five Nations' tournament data. The team that scored the first goal (7 points) won the match on 24 out of 30 occasions. This included 6 out of the 6 matches in the knock-out stages, that is, the quarter-finals onwards. The other two knock-out matches did not have a goal scored. The team that scored the first try (5 points) won the match on 25 out of 31 occasions. This included 7 of the 7 matches in the knock-out stages. The other knockout match, the final, did not have a try scored. The team that scored the first 3 points (penalty or dropped-goal) won the match on 20 of 32 occasions. This included 3 out of the 8 matches in the knock-out stages. The team that scored first, irrespective of what mode of scoring won the match on 21 out of 32 occasions. This included 4 out of the 8 matches in the knock-out stages. The team that was in the lead at half won the match on 26 of 29 occasions. This included 5 of the 6 matches in the knock-out stages. In the other three matches the scores were level at half-time. In summary, the probabilities are as follows:

Probability (Team scoring first goal wins)	=	24/30
Probability (Team scoring first try wins)	=	25/31
Probability (Team scoring first 3 points wins)	=	20/32
Probability (Team scoring first wins)	=	21/32
Probability (Team leading at half-time wins)	=	26/29
Probability (Team kicking-off scores first)	=	18/32
Probability (Team kicking-off scores first and wins)	=	12/31

Thus, the probability that a team wins the match if:

They score first and are leading at half-time	=	21/54
They kick-off, score first and are leading at half-time	=	12/26
They score first goal	=	24/60
They score first try	=	25/62
They score first 3 points	=	20/64
They score first	=	21/64
They are leading at half-time	=	26/58

4.2.5 High Performance Ratings

In recent years, a number of sports have developed world rankings for their member countries. In rugby union and association football, the international governing bodies have such a ranking system based solely on game outcome (win, lose or draw). From this research study it is possible to rank teams with a much more sensitive set of performance indicators.

Table 16 presents performance rankings in the 1996 Five Nations' tournament in relation to six variables: lineouts awarded; scrums awarded; lineout success; scrum success; goal-kick success; and territorial advantage. The top five performances in these indicators are presented in Table 16. Since each team has four performances for each category (one for each game played) it is possible for a team to be ranked more than once in the top five.

Table 16: Top Five Performances in the 1996 Five Nations' Tournament

	Lineouts Awarded (%)	Scrums Awarded (%)	Lineout Success (%)	Scrum Success (%)	Goal-kick Success (%)	Territorial Advantage (%)
1	France 76	England 72	Wales 96	England 91	Scotland 80	England 65
2	Wales 66	Ireland 68	Wales 86	Ireland 88	Ireland 71	England 64
3	Scotland 64	Wales 58	England 86	Scotland 82	England 70	France 64
4	Wales 59	Scotland 56	Ireland 85	France 78	Wales 68	Scotland 60
5	Scotland 59	Ireland 55	Scotland 77	Ireland 75	England 57	England 59

England, the winners, are ranked in first place three times, second place once, third place twice, and fifth place twice. What is important here is that a pattern re-emerges here that was apparent in the statistical tests that looked at winners in respect of the key variables. England have three of the best five performances in the territorial area, and two of the five in the goal-kicking success, but in the primary possession variables they are not as much in evidence.

There are other data in Table 16 which mirror previous findings on the important variables in a winning performance. In terms of territorial advantage, the top five performances were all by winning sides. Contrary to this finding is that four of the top five performances in the number of lineouts awarded were by the losing side. In lineouts awarded and line-out success rate the top performances were by losing sides. The top performance ratings in all but the line-out variables were by winning sides. Table 17 presents data for the 1995 Rugby World Cup. The top eight performances are ranked.

Table 17: Top Eight Performances in the 1995 Rugby World Cup

	Lineouts Awarded (%)	**Scrums Awarded (%)**	**Lineout Success (%)**	**Scrum Success (%)**	**Goal-kick Success (%)**	**Territorial Advantage (%)**
1	W Samoa 66	S Africa 71	S Africa 93	France 100	N Zealand 95	Scotland 78
2	Australia 62	N Zealand 69	N Zealand 90	Canada 100	England 90	Australia 72
3	England 62	Ireland 67	Australia 87	Tonga 100	England 89	Scotland 67
4	N Zealand 60	France 64	Wales 84	N Zealand 100	Australia 83	France 64
5	Tonga 58	S Africa 63	England 81	France 100	Wales 82	England 63
6	S Africa 58	Wales 62	England 81	England 94	S Africa 80	Tonga 63
7	Australia 58	England 59	N Zealand 79	Australia 93	Canada 78	S Africa 62
8	Australia 57	Canada 56	France 79	N Zealand 91	Ireland 78	N Zealand 62

It is important to note that whilst some countries with indifferent tournament records appear in high positions within certain categories, it is the winning sides that are consistently within the top eight. South Africa, the World Cup champions, are present in five of the six categories (in first place twice, fifth place once and sixth place twice); New Zealand, the runners-up are in all six categories (first once, second twice, fourth twice, seventh once, and eighth twice). England and France (who finished third and fourth) are also prominent within the rankings.

4.2.6 The Winning Range

Differences between winners and losers can be further investigated by auditing the range of their performance in relation to a number of indicators. Their locations within these range can be construed as windows of opportunity. The windows of opportunity are shown in Figures 7 to 10.

In the Five Nations' tournament in 1996, the anticipated patterns of higher maxima and minima for the winners and lower ones for the losers only appear to a certain extent. Although losers only have higher minima on four occasions and maxima on three occasions, the ranges are fairly similar. Once again it is apparent that losers do equally as well as winners or even better than them at lineout situations. The two areas that winners do have an advantage are at ruck and maul situations and in the territorial advantage.

In the 1995 Rugby World Cup, the expected patterns of higher maxima and minima for the winners and lower ones for the losers only appear to a certain extent. Losers have higher minima on five occasions and maxima on three occasions and the ranges are fairly similar. Again it is apparent that losers do equally as well as winners or even better at achieving lineout and scrum situations and at their performances in these two aspects. The two areas that winners do have a clear advantage are at the ruck and maul situations and in the territorial advantage.

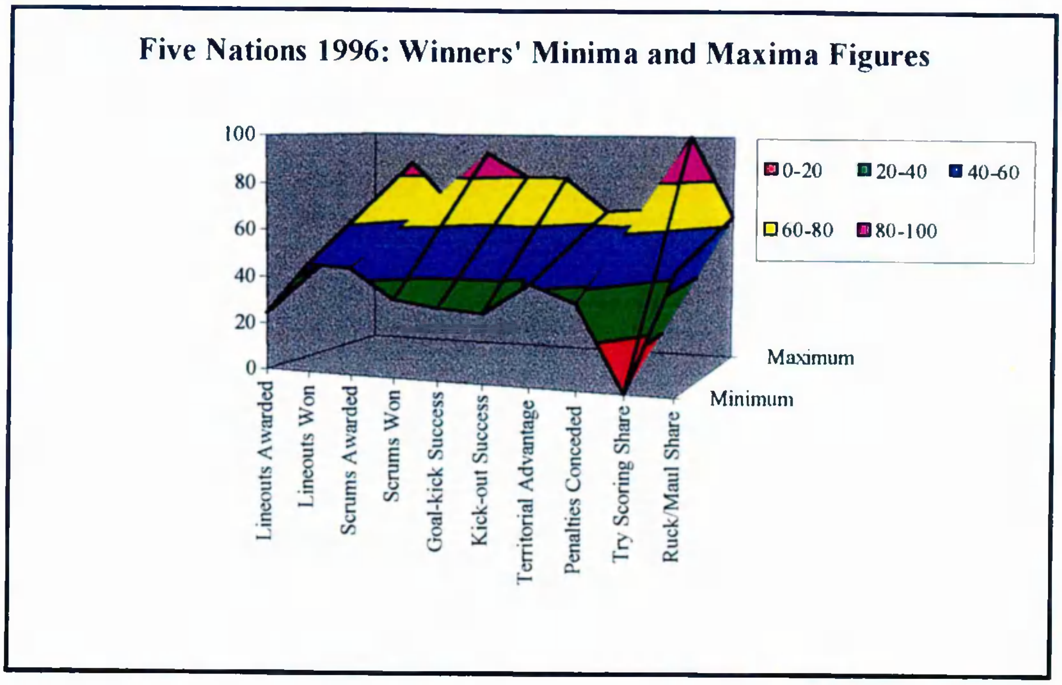

Figure 7: Winners' Minima and Maxima for the 1996 Five Nations' Tournament

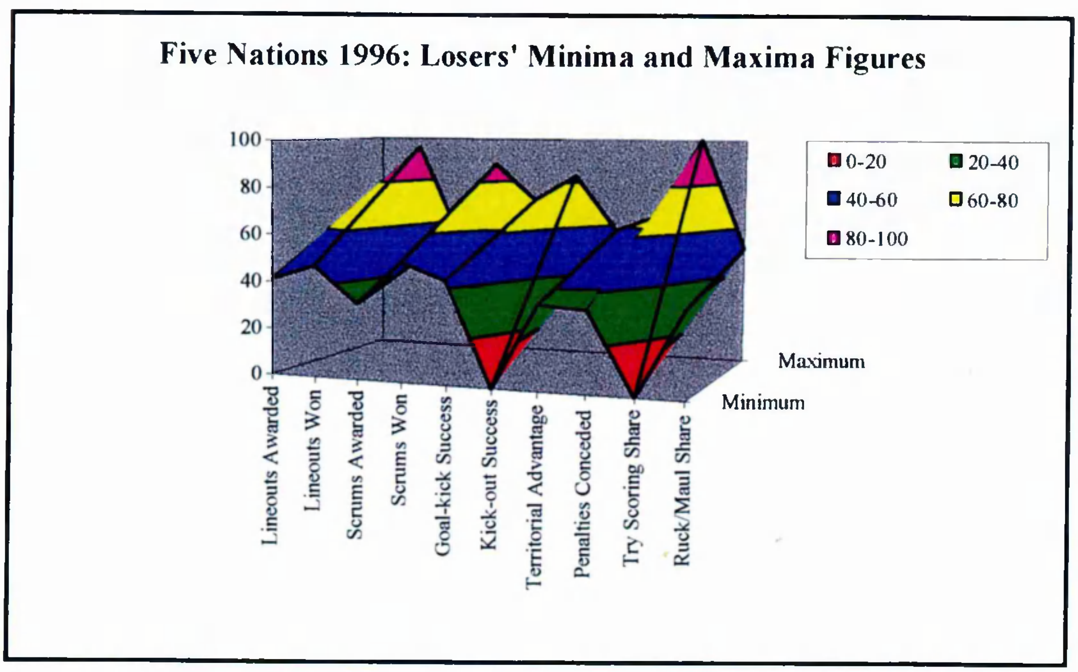

Figure 8: Losers' Minima and Maxima for the 1996 Five Nations' Tournament

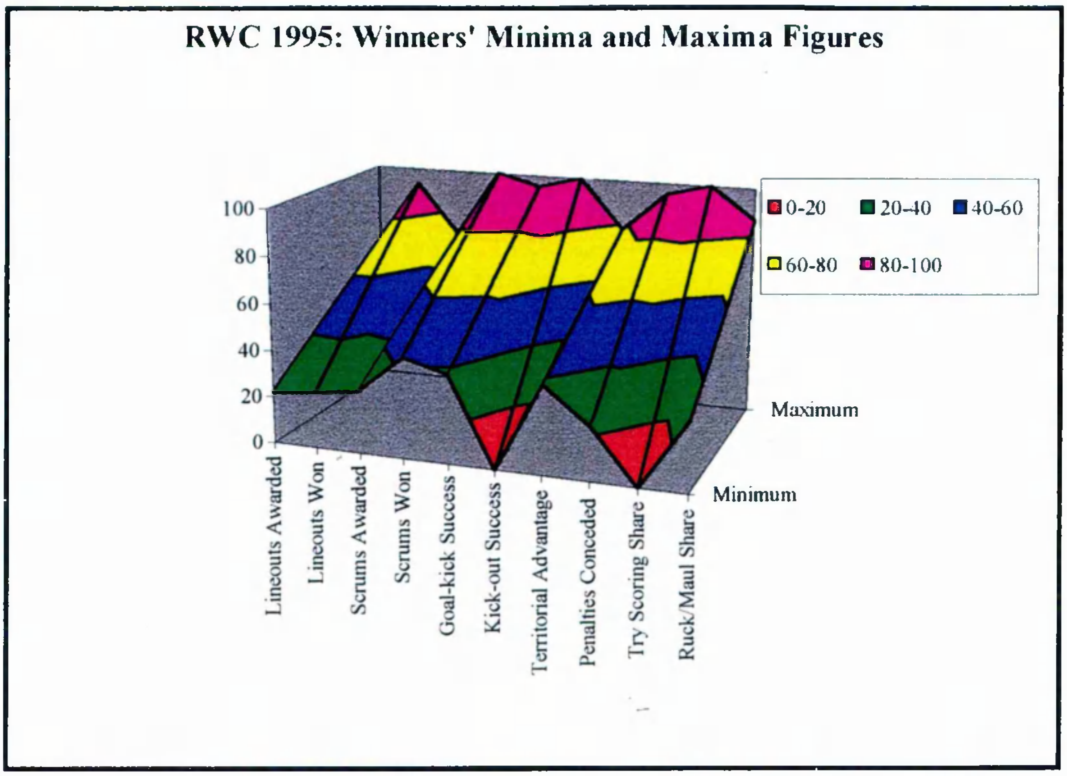

Figure 9: Winners' Minima and Maxima for the 1995 RWC

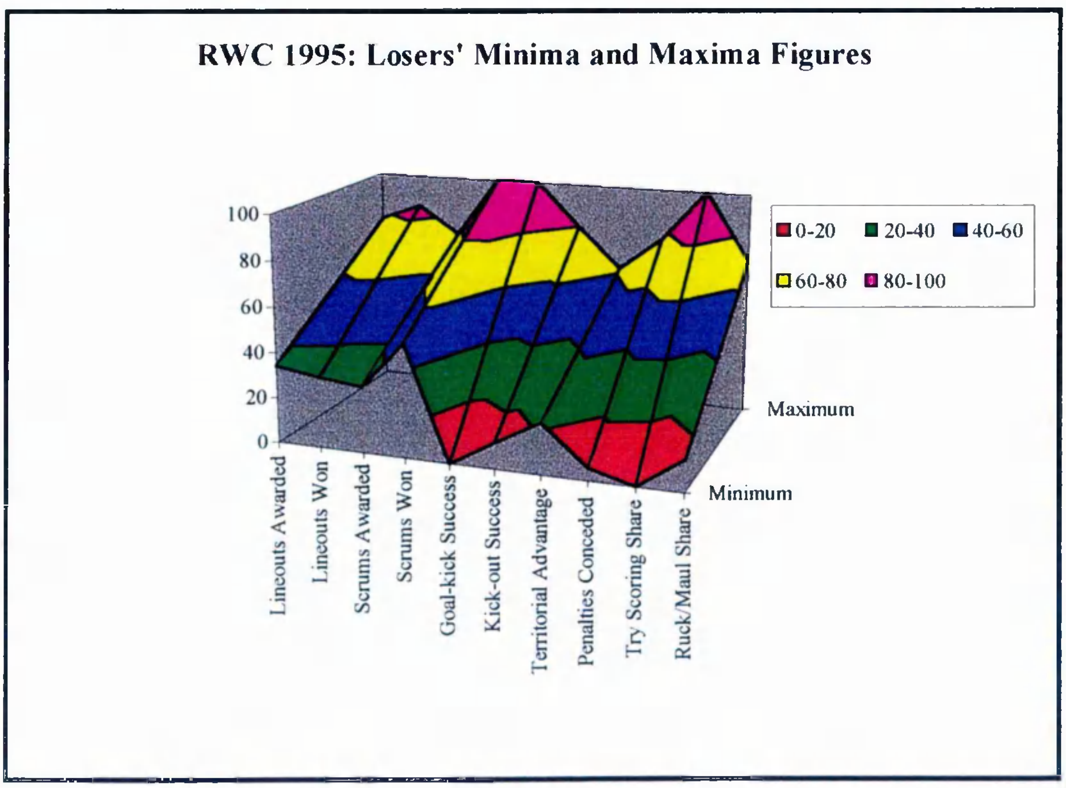

Figure 10: Losers' Minima and Maxima for the 1995 RWC

4.2.7 The Champions

When determining the pattern of winning performance in the Five Nations' tournament in 1996 it is logical to look at the performance of the tournament winners in key performance areas. Table 18 identifies England's performance in relation to ten indicators.

Table 18: England: Statistical Performance in the 1996 Five Nations

England's Performance Indicators (%)				
Variable	**Mean**	**SD**	**Min**	**Max**
Lineouts Awarded	54.27	16.97	35.56	75.86
Lineouts Won	62.40	14.34	46.15	75.00
Scrums Awarded	56.31	10.96	47.83	72.41
Scrums Won	57.40	24.80	33.30	90.90
Goal-kick Success	55.42	12.30	40.00	70.00
Kick-out Success	39.87	17.15	20.00	60.00
Territorial Advantage	58.40	8.97	45.61	64.99
Penalties Conceded	48.24	12.22	36.67	63.16
Try Scoring Share	75.00	35.40	50.00	100.00
Ruck/Maul Share	51.92	8.58	41.10	60.44

In their first match against France in Paris, despite having the greater number of set-piece possessions, they failed to have parity in three vital areas. They had only 46% of the territorial play, only 41% of the number of second phase (ruck/maul) possessions and conceded the majority of the penalties and free-kicks. These key areas of play could be indicative of the losing score-line. In the other three matches although England are not as dominant in gaining more set-piece situations they do perform better at these phases and in the subsequent plays. They have an increasing percentage of the loose possessions as the tournament progresses and this is also mirrored in their territorial dominance. Their discipline is also better than in the first match but there is an evident pattern of home and away here with the English conceding relatively fewer penalties and free-kicks at Twickenham than away from home. Another variable which seems to have a home/away influence is the tries scored - the English scoring more or as many as the opposition at Twickenham but unable to score away from home. However, they prevent the opposition from scoring when in away fixtures. England's mean performance in these areas over the four matches of the tournament are reflective of what one would expect of a winning team's pattern. On average they have more set-piece situations than their opposition. They also display better territorial play, are more disciplined, score the greater number of tries and secure more ruck and maul possessions.

In the Rugby World Cup 1995 South Africa played six matches in total. It is evident from the data that South Africa's progress was based on a steady flow of first phase possession. In five of their six matches they had as many if not more lineouts than the opposition and in every match they had more scrums than the opposition. Their performance on their own ball is also of a high standard. In their first match against Australia they had more set-piece plays than the opposition, their kicking game was effective in terms of goal-kicking and restarting of the game, they were more disciplined and had greater territorial dominance. Surprisingly though, they did have fewer second phase possessions. Against Romania and Canada in the other pool matches the pattern was again established - a greater share of the set-pieces, territorial control, a disciplined approach in terms of penalties and set-piece kicking. Once again the dominance in terms of continuity of play was not as evident as expected. Their match against Western Samoa in the quarter-final was their most efficient with regards to the performance indicators. They dominated every aspect of play and the only indicator which did not measure up to the standards they had set themselves was the goal-kicking. The semi-final and final were close matches as one would expect but the South Africans still based their play on achieving at least parity at the set-pieces and they know managed to exhibit better continuity than their opponents. The key indicator of territorial dominance was once again in favour of the South Africans as it had been for every match in the tournament. South Africa's mean performance in these areas over the six matches of the tournament are reflective of what one would expect of a winning team's pattern. On average they have more set-piece situations than their opposition and display an effective strike rate at winning their own ball. They also display better territorial play, are more disciplined, score the greater number of tries and have an extremely effective kicking game. The one surprise though is that they only secured as many ruck and maul possessions as their opponents. This raises the question of when were the respective sides recycling the ball - was it consistently throughout the match or did South Africa have the greater continuity until they were in a winning position and then the losers started to play a more expansive game and had to recycle the ball to attempt to catch up with the leaders. Overall South Africa's performance in the 1996 Five Nations tournament does mirror the expected performance of winners. Data on South Africa's performance are presented in Table 19.

Table 19: South Africa: Statistical Performance in the 1995 Rugby World Cup

South Africa's Performance Indicators (%)				
Variable	**Mean**	**SD**	**Min**	**Max**
Lineouts Awarded	52.40	4.99	45.45	59.18
Lineouts Won	66.29	11.73	52.00	82.35
Scrums Awarded	59.99	7.42	51.72	72.22
Scrums Won	75.53	11.77	61.11	93.33
Goal-kick Success	64.60	15.41	38.46	80.00
Kick-out Success	59.80	31.00	22.20	100.00
Territorial Advantage	56.25	4.07	51.25	61.42
Penalties Conceded	45.92	13.99	26.92	64.29
Try Scoring Share	78.33	21.73	50.00	100.00
Ruck/Maul Share	49.69	10.23	33.72	57.69

4.2.8 Possession Count

The ten matches in the 1996 Five Nations' tournament were analysed using a computerised notation system. The data discussed here are the absolute figures for the winning and losing team in each game. The number of possessions won at the line-out and scrum situation are examined as well as the retention of this possession through phase rugby, that is, rucks and mauls won. The data are further examined by, firstly, combining the lineouts and scrums and grouping them as primary possessions and, secondly, combining all aspects to have a total possession count in terms of primary and secondary possession.

Table 20: Possession Count in the 1996 Five Nations' Tournament

	Lineouts		Scrums		Rucks & Mauls		Primary Possession		Primary & Secondary Possession	
Match	**Win**	**Lose**	**Win**	**Lose**	**Win**	**Lose**	**Win**	**Lose**	**Win**	**Lose**
1	13	13	14	12	43	30	27	25	70	55
2	15	20	14	14	53	46	29	34	82	80
3	7	16	7	5	34	35	14	21	48	56
4	18	15	11	10	37	24	29	25	66	49
5	15	21	9	10	49	30	24	31	73	61
6	11	13	11	15	49	43	22	28	71	71
7	10	22	14	8	45	25	24	30	69	55
8	19	25	5	5	29	22	24	30	53	52
9	19	13	13	9	47	30	32	22	79	52
10	19	15	10	9	55	36	29	24	84	60
Total	146	173	108	97	441	321	254	270	695	591
%	45.8	54.2	52.7	47.3	57.9	42.1	48.5	51.5	54.0	46.0
Mean	14.6	17.3	10.8	9.7	44.1	32.1	25.4	27.0	69.5	59.1

Overall the winners have more: scrum possession; ruck and maul possession; combined primary possessions; and combined primary and secondary possessions. However they do not have more line-out possession. The trend appears to be for winners to win more possession in eight of the matches, and to win more ruck and maul possession in nine of the matches but in terms of primary possession the winners only gain more possession in three matches in terms of lineouts and six matches in terms of scrums. However, the overall possession count is in favour of the winners in eight of the ten matches. In terms of the line-out count teams still won the match with as few lineouts won as seven and with as many lineouts less than the losers as twelve. Similarly teams still won the match with only five possessions from scrummages but here the difference in scrums won between winners and losers was never more than four. When both lineouts and scrums are examined together as primary possession then winners still do not achieve as much possession as losers. They won more possession in four of the ten games but on the other occasions they were not within six primary possession counts of the losers.

In terms of the correlation between each variable and the winning margin of a game, none of the variables were significant at either the 0.05 level or 0.01 level. This is possibly due to the small size of the data set.

The thirty two matches in the 1995 Rugby World Cup were analysed in the same way (see Table 21). Overall the winners have more possession in each aspect, but only marginally so in many of the variables. As individual cases, the trend appears to be winners winning more possession in approximately two thirds of the matches in each variable. However, the possession profile does vary so that in some matches winners win more lineouts but fewer scrums or vice versa.

In the 31 matches (one ended in a draw) the winners won more lineouts 21 times, more scrums 16 times, more primary possession 23 times, more rucks and mauls 18 times, and more primary and secondary possession 19 times. In terms of the line-out count teams still won the match with as few lineouts won as eight or nine and with as many lineouts less than the losers as twenty. Similarly teams still won the match with only four or five possessions from scrummages and with as much as nine fewer possessions as the losers. When both lineouts and scrums are examined together as primary possession then winners do tend to become more dominant. They won more possession 23 times out of the 31 and on the other occasions were within two possessions of the losers on four occasions and within for and five in a further two instances. However, in the remaining two matches they have considerably less possession: thirteen less in one and fifteen less in the other.

Table 21: Possession Count in the 1995 Rugby World Cup

	Lineouts		**Scrums**		**Rucks & Mauls**		**Primary Possession**		**Primary & Secondary Possession**	
Match	**Win**	**Lose**	**Win**	**Lose**	**Win**	**Los**	**Win**	**Lose**	**Win**	**Lose**
1	11	2	14	11	32	48	25	13	57	61
2	23	10	5	12	55	9	28	22	83	31
3	14	7	10	10	27	55	24	17	51	72
4	9	29	19	14	39	12	28	43	67	55
5	19	8	7	15	40	26	26	23	66	49
6	23	12	12	5	52	43	35	17	87	60
7	25	10	11	7	40	43	36	17	76	60
8	22	13	6	10	26	29	28	13	54	42
9	10	10	13	12	28	41	23	22	51	63
10	27	19	11	7	39	30	38	26	77	56
11	16	10	7	8	54	15	23	18	77	33
12	20	12	9	9	41	26	29	21	70	47
13	13	8	15	16	42	53	28	24	70	77
14	8	13	10	10	49	63	18	23	67	86
15	23	24	16	13	34	28	39	37	73	65
16	17	13	5	8	32	29	22	21	54	50
17	17	11	14	13	39	18	31	24	70	42
18	28	19	5	10	56	34	33	29	89	63
19	25	17	9	11	38	44	34	28	72	72
20	18	15	6	18	29	57	34	33	63	90
21	16	18	8	7	29	56	24	25	53	81
22	9	5	4	0	42	30	13	5	55	35
23	16	18	10	9	27	33	26	27	53	60
24	16	18	7	7	45	38	23	25	68	63
25	20	9	13	11	55	19	33	20	88	39
26	17	10	9	6	38	33	26	16	64	49
27	12	16	9	18	39	34	21	34	60	68
28	14	12	10	3	36	24	24	15	60	39
29	20	19	13	10	30	22	33	29	63	51
30	9	10	10	9	18	49	19	19	37	68
31	15	18	15	16	39	59	30	34	69	93
Total	532	415	322	315	1190	1100	854	730	2044	1820
%	56.2	43.8	50.6	49.5	52.0	48.0	53.9	46.1	52.9	47.1
Mean	17.2	13.4	10.4	10.2	38.4	35.5	27.6	23.6	66.0	58.8

In terms of the correlation between each variable and the winning margin the following were significant at the 0.05 level (>0.306):

Negative: Scrums won by the winners (0.426), Rucks and Mauls won by the losers (0.335), Primary possession won by the losers (0.401), Primary and Secondary possession won by the losers (0.495).

Positive: Rucks and Mauls won by the winners (0.52).

In terms of the correlation between each variable and the winning margin the following were significant at the 0.01 level (>0.432):

Negative: Primary and Secondary possession won by the losers (0.495).

Positive: Rucks and Mauls won by the winners (0.52).

4.2.9 The Yes/No Challenge

For a certain number of performance categories or sub-categories the respective figures for both the winners and losers were recorded for each match and compared. The number of times the winning side had greater success than the losers was recorded for each variable. Ten matches were recorded in the 1996 Five Nations' tournament.

It was only in one aspect (ruck and maul possession won on own ball) that the winners always performed better than the losers, but in nine of the matches the winners enjoyed more ruck/mauls won, territorial dominance and time in control and in eight of the matches had better figures in terms of times in the opposition 22 metre area, rucks/mauls set-up, turning over the opposition and total number of successful kicks. The aspects that stand out here as a winning profile are: a team's ability to retain the ball particularly at the second phase situations; territorial dominance; and pressure exerted on the opposition.

The next step was to discover whether winners had overall dominance in the majority of the variables in any match. Although this was the case it was not one of any great strength. The ten matches were again analysed. In 6 of the 10 matches winners only had better results in 15 or fewer of the 24 variables but in 4 matches in 18 variables or over. There is evidently a link between the variables chosen to measure performance and the end result but it does not appear that all, or the majority of the variables, are key factors in a winning profile.

In an attempt to identify groups of key performance indicators, the variables were divided into five categories: territorial pressure (territorial dominance and times in opposition 22 metre area); primary possession (scrum and line-out ball won); disciplined play (penalties and free-kicks awarded); effective kicking game (success in all aspects of kicking game); and ball retention (time in control, rucks and mauls won). With the variables grouped together in these categories, it is possible to identify which categories seem to characterise winning performance. Ball retention, for example, seems to be the key performance area in this respect: winning teams enjoying a dominance in this area in nine of the matches. In addition, both territorial dominance and a superior kicking success were key areas. To a lesser extent discipline and primary possession were factors for winning sides. This does raise the question of necessary and sufficient factors in a winning performance. Although primary possession was not as important as some other areas, there is no question that a certain amount of primary ball and a certain level of discipline are required. Winning would not be possible without these levels.

It was important to investigate whether these categories were mutually exclusive or were dependent upon each other. Was it possible to win a match by not achieving dominance in all these areas? The winning side achieved better results than losers in all five categories in three games (Scotland v France; Ireland v Wales; Wales v France). In three matches the winning side achieved better results in four of the categories (France v England; England v Wales; England v Ireland). The winning side dominated three categories in three matches (Wales v Scotland; France v Ireland; Scotland v England) and once in two categories (Ireland v Scotland).

The twenty-four performance categories or sub-categories the respective figures for both the winners and losers was also recorded and compared for each match in the 1995 Rugby World Cup. The number of times the winning side had greater success than the losers was recorded for each variable. Thirty one matches leading up to the drawn final were recorded.

In not one match did the winners consistently perform better than the losers but in a data set of this size this not a surprising finding. The variables in which the winners were most consistent (over two-thirds of the time) at performing better than the losers were:

1. Goal-kicking success (28 of the 31 matches)
2. Try time (26 of the 31 matches)
3. Tries scored (25 of the 31 matches)
4. Defence time (25 of the 31 matches)
5. Territorial dominance (22 of the 31 matches)
6. Times in opposition 22m (22 of the 31 matches)
7. Total number of successful kicks (22 of the 31 matches)

The next step was to discover whether winners had overall dominance in the majority of the variables in any match. This was not the case. In 15 of the 31 matches winners had better results in 15 or more of the 24 variables but in 16 of the matches in less than 14 of the variables.

As with the 1996 Five Nations' tournament data, the variables were divided into five categories: territorial pressure (territorial dominance and times in opposition 22 metre area); primary possession (scrum and line-out ball won); disciplined play (penalties and free-kicks awarded); effective kicking game (success in all aspects of kicking game); and ball retention (time in control, rucks and mauls won). With the variables grouped together in these categories, it is possible to identify which categories seem to characterise winning performance. In the 1995 Rugby World Cup, it appears that primary possession is an important category.

In four matches the winning side achieved better results than the losing side in all five categories (Scotland v Ivory Coast, Canada v Romania, Scotland v Tonga, and South

Africa v Western Samoa). Only one side managed dominance in only one area (territory) and won (France in their match against England). In ten matches the winning side dominated four of the categories, and in nine matches they achieved three dominant categories and in seven matches two dominant categories.

4.2.10 Spearman's Rank Correlation Coefficient

The performance of the winning side in each of the 1996 Five Nations' tournament matches was notated and analysed. The results for each variable identified were then tested for their significance in relation to the winning margin through Spearman's Rank Correlation Coefficient. One limiting factor was the size of the data set since only ten matches were played in the tournament. The data collected were grouped in five sections: territory and try-scoring; primary possession; discipline; kicking; and ball retention.

Five variables were recorded in terms of territory and try scoring: (territorial dominance, times in opposition 22 metre area, times in own 22 metre area, tries scored and tries conceded); and from these a further two variables were calculated (try time and defence time). Correlation coefficient values were then tested for significance at both the 0.05 and 0.01 level. At the 0.05 level both territorial dominance and times in the opposition 22 metre area had a significant correlation with the winning margin while at the 0.01 level only the territorial dominance was significant.

The winner's performance was recorded for line-out and scrum situations. The total number of lineouts and scrums awarded, their success rate on their own feeds as well as the total number won were noted. Correlation coefficient values were tested for significance at both the 0.05 and 0.01 level. At neither the 0.05 or the 0.01 level did any of the primary possession variables have any significant correlation with the winning margin.

In order to investigate the role of ball retention in winning performance, the ability to maintain possession from primary possession was measured at both rucks and mauls. The following were noted: overall time that the team was in possession of the ball; the total number of rucks and mauls set-up; the team's ability to recycle ruck and maul ball; and their ability to turnover opposition ball. Only one variable, number of ruck and maul possessions turned over by the opposition, had a significant correlation with the winning margin and this was a negative relationship at the 0.05 significance level. This is expected since the importance of not conceding turnovers to the opposition is stressed as a key factor by coaches and the more that were conceded then one would expect the chances of winning to diminish.

The only measure of discipline analysed was that of the number of penalties and free-kicks conceded and awarded. Where on the pitch penalties were conceded was also noted. The correlation coefficient levels were generally stronger in this category but were again not significant at any of the confidence levels.

Each kick and whether the outcome of it was successful or not was notated. The kicks were sub-divided into categories depending on whether they were touch kicks, goal-kicks, restarts from the half-way or 22 metre line or tactical kicks. Once more there was no significant relationship with the winning margin and these kicks.

The performance of the winning side in each of the 1995 Rugby World Cup matches was also notated and analysed. The results for each variable identified were then tested for their significance in relation to the winning margin through Spearman's Rank Correlation Coefficient. The limiting factor previously encountered with the Five Nations' data set, the size of the data set being only ten matches, was overcome since there were 31 matches played in the tournament with a winning outcome. The data collected were grouped in five sections: territory and try-scoring; primary possession; discipline; kicking; and ball retention.

Five variables were recorded in terms of territory and try scoring (territorial dominance, times in opposition 22 metre area, times in own 22 metre area, tries scored and tries conceded) and from these a further two calculated (try time and defence time). Correlation coefficient values were then tested for significance at both the 0.05 and 0.01 level. At the 0.05 level territorial dominance, times in the opposition 22 metre area, tries scored and try time had a significant positive correlation with the winning margin while the number of times in one's own 22 metre area had a significant negative correlation. At the 0.01 level territorial dominance, times in opposition 22m area and number of tries scored were significant.

Winners' performance was recorded at both line-out and scrum situations. The total number of lineouts and scrums awarded, their success rate on their own feeds as well as the total number won were noted. Correlation coefficient values for performance at the line-out and scrums were once again tested for significance at both the 0.05 and 0.01 level. At neither the 0.05 or the 0.01 level did any of the primary possession variables have any significant correlation with the winning margin.

In order to investigate the role of ball retention in winning performance, the ability to maintain possession from primary possession was measured at both rucks and mauls. The following were noted: overall time that the team was in possession of the ball; the total number of rucks and mauls set-up; the team's ability to recycle ruck and maul ball; and their ability to turnover opposition ball. At the 0.05 level of confidence the time in control of the ball, the number of rucks and mauls formed (both absolute and relative to the opposition), the number of rucks and mauls won on own feed, the total number of second phase possessions won (absolute and relative) and the number of opposition rucks and mauls turned-over had a significant positive relationship. At the 0.01 level, though, it was only the total time in control, and the total number of rucks and mauls won in both frequency and percentage terms that were significant.

The only measure of discipline analysed was that of the number of penalties and free-kicks both conceded and awarded. For penalties and free-kicks their relation to area of the field was additionally recorded. There was no significant correlation between any of the discipline variables and the winning margin.

Each kick was notated and whether the outcome was successful or not. The kicks were sub-divided into categories depending on whether they were touch kicks, goal-kicks, restarts from the half-way or 22 metre line and tactical kicks. In terms of kicking strategy the touch kicking success and overall kicking success are significant at the

0.05 level but only the total successful kicking rate has a significant positive correlation at the 0.01 level. As with the Five Nations data this raises the question of whether it is the number or the proportion of successful kicks which is the important factor.

4.2.11 Performance Profile

Each country's performance in each of the variables was measured for every match in the 1996 Five Nations' tournament. This yielded total figures and average figures for each country. From these data it was possible to profile each country's performance. The average performance of each country in each match is correlated with their final position in the tournament. Their final positions were:

1. England
2. Scotland
3. France
4. Wales
5. Ireland

At the 0.05 confidence level the variables which had a significant correlation with the team's final placing in the 1996 Five Nations' Championship were:

Positive correlation:	Winning margin	Defence time
	Total lineouts awarded	Total lineouts won
	Ruck and maul share	Total rucks/mauls won
	Penalty/Free-kicks conceded	

Negative correlation:	Times in own 22 metre area	Try time
	Tries scored	Tries conceded
	Own scrums lost	Total scrums won (%)
	Time in control (%)	Ball in play (%)
	Ruck and maul steals	Restart kicking success
	Penalty/Free-kicks conceded own 22m to half-way	

At the 0.01 confidence level the variables which had a significant correlation with the team's final placing in the 1996 Five Nations' Championship were:

Positive correlation:	Defence time	Total lineouts awarded
	Ruck and maul share	

Negative correlation:	Times in own 22 metre area	Try time
	Tries conceded	Own scrums lost
	Ruck and maul steals	Restart kicking success
	Penalty/Free-kicks conceded own 22m to half-way	

Similarly, each country's performance in each of the variables was measured for every match in the 1995 Rugby World Cup. This provided total and average figures for each country. This facilitated a correlation of each country's performance. Their average performance in each match is correlated with their final position in the tournament. Their final position was calculated by:

1. South Africa, the winners were placed first.
2. New Zealand, the runners-up were placed second.

3. France, winners of the 3rd and 4th place play-off, were placed third.
4. England, losers of the 3rd and 4th place play-off), were placed fourth.
5. Ireland, Western Samoa, Scotland and Australia, all losing quarter-finalists, were placed equal fifth.
6. Wales, Tonga, Italy and Canada, all third in their qualifying group, were placed equal ninth.
7. Ivory Coast, Japan, Argentina and Romania, all fourth in their qualifying group were placed equal thirteenth.

At the 0.05 confidence level the variables which had a significant correlation with the team's final placing in the 1995 Rugby World Cup were:

Positive correlation:	Winning margin	Territorial dominance
	Times in opp 22 metre area	Tries scored
	Try time	Defence time
	Own lineouts won (%)	Total lineouts won (%)
	Total lineouts won	Time in control
	Total rucks and mauls won	Goal-kicking success
	Restart kicking success	Other kicking success
	Total kicking success	Total successful kicks
Negative correlation:	Times in own 22 metre area	Tries conceded
	Lineout share	Total lineouts awarded
	Own lineouts lost	Total lineouts opp won
	Ruck and maul steals	Ruck and maul turnovers
	Penalty/Free-kicks conceded own 22m to half-way	
	Penalty/Free-kicks conceded own 22 metre area	

At the 0.01 confidence level the variables which had a significant correlation with the team's final placing in the 1995 Rugby World Cup were:

Positive correlation:	Winning margin	Territorial Dominance
	Tries scored	Defence time
	Own lineouts won (%)	Goal-kicking success
	Total kicking success	Total successful kicks
Negative correlation:	Times in own 22 metre area	Tries conceded
	Own lineouts lost	Total lineouts opp won
	Ruck and maul steals	Ruck and maul turnovers

4.2.12 The Game Rhythm

Game rhythm charts or time signatures were incorporated into the computer analysis system so that the data could viewed in a different way. The use of gross performance indicators in the modelling of winning performance was considered as important but had its limitations. An oft talked about phenomenon in rugby union over the past decade has been that of "catch-up rugby" where a losing side has to mobilise the game in the closing stages of the match so that they can narrow the opponents lead.

This often results in many of the gross performance indicators such as time in possession and recycled possessions evening out over the course of a game. Thomas (1997) has indicated the bias that officials have towards losing sides in the final stages in awarding the majority of the penalties and free-kicks. The chronological logging of data in the computer system enabled the data to be illustrated in a sequential form that might have a greater bearing on identifying patterns of play at various stages of the match. The following pages are examples of game rhythms and illustrate one match from the 1996 Five Nations' tournament and one match from the 1995 Rugby World Cup.

The aim of the game rhythm profile is to link together all the performance indicators previously monitored in one visual representation to see which ones work together to provide a winning edge. The Ireland v Scotland match (20 January 1996) illustrated in Figure 11 was interesting in that all the scoring events were within the first half.

The ball in play and possession signatures are evidence of the stop-start nature of rugby union matches and the long intervals that exist between each activity cycle. Territorial dominance was identified as a key variable over the whole course of a match and this is further emphasised here. Scotland clearly had dominance in the first half and managed to score four times out of their eleven visits in the Irish 22 metre. Ireland do not have any extended periods of time in the opponents' half until ten minutes into the second half. They then have dominance for most of the remaining time, but it must be noted that they are losing the match during this stage.

The striking feature of the game rhythms are the phase of play signatures which illustrate a team's ability to retain possession of the ball. Scotland had slightly more possession in the first half and they further consolidate this pattern in the first quarter of the second half. Apart from the occasional continuity passages in the first half, Ireland's retention is limited to two key periods. Firstly, there is the characteristic, initial Irish surge in the first few minutes of the match, the second is the final fifteen minutes where the Irish are forced to play a more expansive game to claw their way back into the game.

The signatures are an instant method of recalling the number of possessions leading to scores. Scotland's second score of the first half came following fourth phase possession (a staircase of blue reaches a fourth line) and the final score of the first half came from Irish fifth phase possession (green staircase).

The other six signatures are frequency-based and the success on each one can be extracted. For example, a green beat upwards means a successful lineout or scrum for the Irish on their own throw, a downward green beat means that the Irish lost one of their own lineouts or scrums. The appeal of the game rhythm is the ability to link each indicator, for example, just prior to the 25th minute of the second half, Ireland win possession from their own lineout throw-in and set-up a series of rucks or mauls which they win, this corresponds with a green staircase of possession in the phase of play signature, Irish territorial dominance and possession for the entire ball in play time of the cycle.

The 1995 Rugby World Cup game rhythm illustrated is the match between South Africa and Canada (4 June 1995). This match is an excellent example of a "game of two halves". The first half comprises a large number of short activity cycles. South Africa have long periods of territorial dominance and capitalise on two of the periods with converted tries after pressure within the Canadian 22 metre area. It is not until injury time of the first half that the Canadians begin to have an influence on the game.

They are now 17 - 0 down and respond with five continuity passages of five phases or more, eight phases on one occasion.

The second half has much longer periods of play and Canada are dominant in both territory and possession. It is the classic "catch-up" situation but they do not take advantage of their dominance.

Game rhythms are a definite progression in the illustration of a game's pattern but there are still disadvantages of such graphical output. Was Canada's failure to score a result of poor attacking decisions or good South African defence? It is probable that it was a combination of both aspects but this is not evident from the signatures. There is no qualitative information to be gained from the graph.

It was intended to develop the game rhythm to extract critical incidents from the visual representation of the data. However, although the game rhythms have aided in identifying micro-situations within the match, they do not act, at present, as a microscopic view of what occurred.

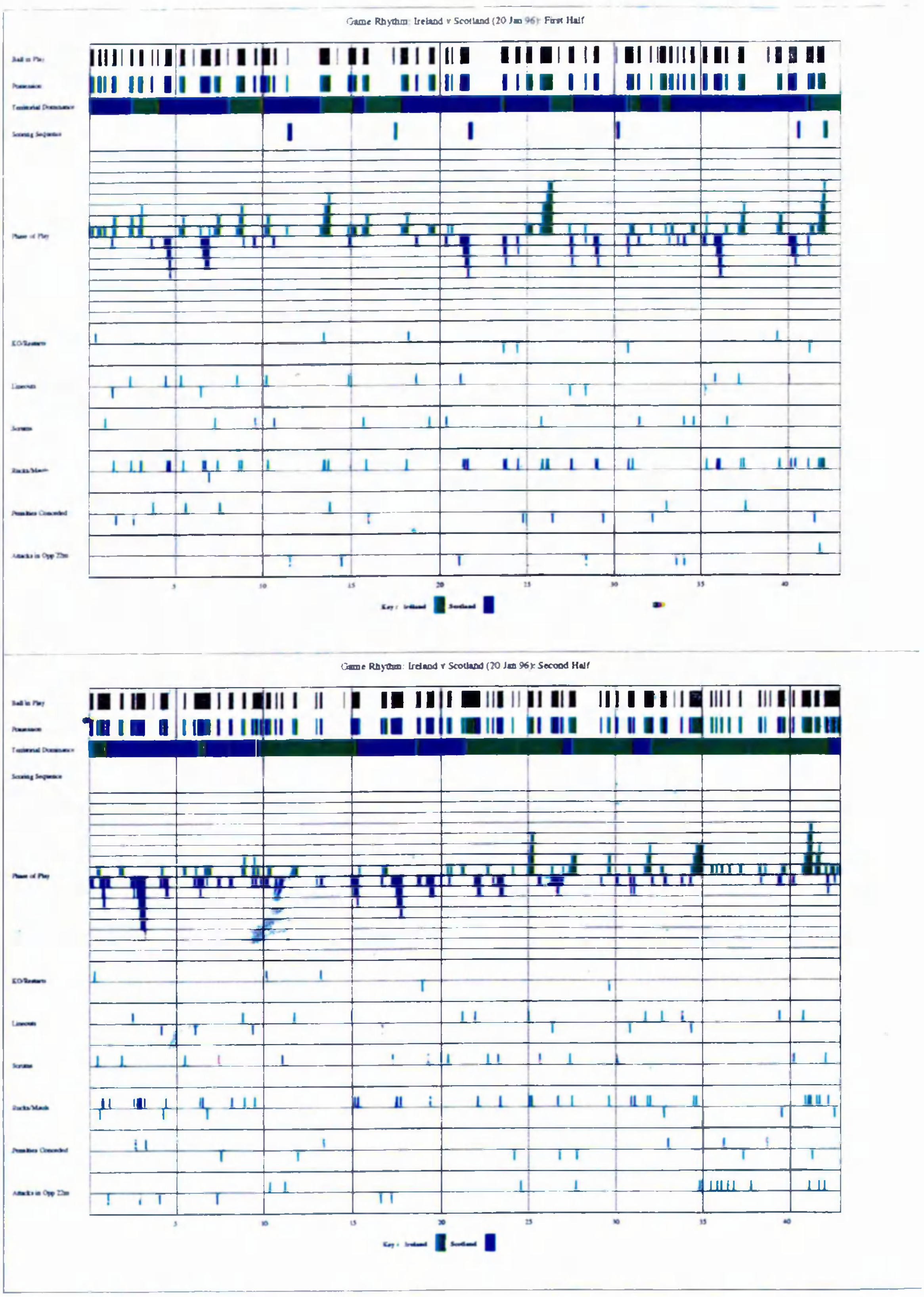

Figure 11: Game Rhythm Chart: Ireland v Scotland (20 January 1996)

4.2.13 Time Intervals

In order to enrich the discussion of winning and losing performance, it was thought important to investigate the temporal dimensions of performance. To this end each game was divided into ten-minute periods. Winning and losing teams were examined as individual cases and as collective categories. In addition, a chi-square test was carried out for each variable to determine whether there was a significant difference in the proportions of winners and losers within each time interval. If the calculated value exceeded the critical value in the table, then the null hypothesis was rejected.

In the 1996 Five Nations' Championship, winning teams displayed a pattern of concerted periods of pressure over a short time scale. Within each 10 minute period of the matches, winners, on average, had 10 periods of being in the opposition 22 metre area on 4 occasions or more. The corresponding figure for losers is only four times, and each of these four occurrences happen during the final quarter of the match from the 61st minute onwards when the side is either losing or drawing. In two of the ten matches the winning side had fewer entries than the losing side. In both these cases the winners were playing away from home. Winning teams had more entries into the opposition 22 metre area in 7 of the 9 ten minute periods. The only two periods in which they did not was 61 - 70 minutes and 81 - 90 minutes periods when the losing sides often exert pressure as they attempt to play catch-up rugby to overturn the score deficit. In this final quarter of the match the number of entries of both the winners and losers were equal at 40 apiece. In the previous three-quarters of the game, the winners had a 90-49 advantage. The null hypothesis is that there is no significant difference in the proportion of entries into the opposition 22 metre area between winners and losers.

The chi square value for the number of times winners and losers were in the opposition 22 metre area was 9.571, and at the appropriate degree of freedom value, this was more than the value in the 0.99, 0.95 and 0.90 probability columns, indicating there is a significant difference between the proportion of entries into the opposition 22 metre area made by winners and losers within the time intervals.

The number of tries scored by winners and losers in the 1996 Five Nations' Championship revealed the following pattern. In nine of the ten matches the winners scored the first try, and also in nine of the matches the winners outscored the opposition in total number of tries scored. No losing side managed to score in the first ten minutes of a game whereas three scored in the final ten minute interval of a game, that is, in the time added on for injury. The overall try count was two to one (20-10) in favour of winners. In the first half of the games, winners scored 11 tries to losers' 4 but in the second half it was closer at 9 to 6 respectively. The chi square was carried out but was not valid because the values in each time interval should be more than five and the sum of the frequencies should exceed 50. This was not the case for the tries scored data.

The number of goal-kicks successfully converted by winners and losers in the 1996 Five Nations' Championship revealed the following pattern. In every match of the tournament the winning side kicked more or as many successful goal-kicks as the losers. In eight of the nine time intervals the winners had more successful goal-kicks than the losers, with the losers only succeeding with more in the first ten minute interval. The half by half split was 19-13 in the first half and 25-16 in the second half.

As with the tries scored, the successful goal-kick data could not be tested for significance because the number of values less than five.

Analysis of the number of lineouts awarded to winners and losers in the 1996 Five Nations' Championship revealed the following. There is no evident pattern in the number of lineouts awarded in each match of the tournament. In six matches the winners have more throws but in four the losers have more. When each ten minute interval is considered for winners and losers then once again the pattern is variable with neither team consistently being awarded more or fewer lineouts in each ten minute period. The losers do have a large number of throw-ins in the first ten minutes of a match (36 to the winners' 21) and in the final period (9 to 3) and overall they have more lineouts (199 to 165). The null hypothesis is that there is no significant difference in the proportion of lineouts awarded between winners and losers. The chi square value for the number of lineouts awarded to winners and losers was 12.014, and at the appropriate degree of freedom value, this was more than the value in the 0.99, 0.95 and 0.90 probability columns, indicating that there is a significant difference between the proportion of lineouts awarded to winners and losers in the nine time intervals.

As with the lineouts awarded there is no evident pattern in the number of lineouts won in each match of the tournament. In seven matches the losers win more throws than the winners. When each ten minute interval is considered the losers win more lineouts in all but one of the periods, 11th-20th minute. The null hypothesis is that there is no significant difference in the proportion of lineouts won between winners and losers. The chi square value for the number of lineouts won by winners and losers was 3.959, and at the appropriate degree of freedom value, this was more than the value in the 0.99, 0.95 and 0.90 probability columns, indicating there is a significant difference between the proportion of lineouts won by winners and losers.

Winners were awarded more scrums in seven of the ten time periods. The overall count was 163-139. In the first half the count was 69 to 52, both sides having more feeds in the second half. The null hypothesis is that there is no significant difference in the proportion of scrums awarded between winners and losers. The chi square value for the number of scrums awarded to winners and losers was 8.635, and at the appropriate degree of freedom value, this was more than the value in the 0.99, 0.95 and 0.90 probability columns, indicating there is a significant difference between the proportion of scrums awarded by winners and losers at the various intervals of a match.

In nine of the ten matches the winners won at least as many scrums if not more than the losers. This is an important link with the scrums awarded where there was no significant advantage. It indicates that winners are more efficient at winning their own ball at scrum situations. The winners had more scrum ball than the losers in all but two of the time intervals, where again there was a predominance of scrums in the second halves of the matches. The null hypothesis is that there is no significant difference in the proportion of scrums won between winners and losers. The chi square value for the number of scrums won by winners and losers was 3.089, and at the appropriate degree of freedom value, this was more than the value in the 0.99 and 0.95 probability columns indicating there is a significant difference between the proportion of scrums won by winners and losers within the designated time intervals.

The winning team set up more rucks and mauls in eight of the ten matches. There were also 16 occasions when the winners set-up ten or more rucks in a particular ten minute period, with a maximum figure of 15. The corresponding figures for losing teams were 7 intervals with ten or more second phase possessions set-up and a maximum of 12. In total winning sides set-up 520 rucks and mauls as compared to 423 by the losers. They set-up more in each of the ten minute intervals with the exception of both ten minute periods at the end of each half. The null hypothesis is that there is no significant difference in the proportion of rucks and mauls formed between winners and losers. The chi square value for the number of rucks and mauls formed by winners and losers was 19.09, and at the appropriate degree of freedom value, this was more than the value in the 0.99, 0.95 and 0.90 probability columns, indicating once again that there is a significant difference between the proportion of rucks and mauls formed by winners and losers.

The winning team won more ruck and maul ball in every match and there were 6 instances when they won over 10 in a 10 minute interval. Losers only managed two instances with double figure loose possession. In total the winners heavily dominated rucks and mauls won with over 400 as compared to the losers who had less than three hundred. The losers only managed to have more rucks and mauls in the last ten minute interval of the match. The null hypothesis is that there is no significant difference in the proportion of rucks and mauls won between winners and losers. The chi square value for the number of rucks and mauls won by winners and losers was 11.562, and at the appropriate degree of freedom value, this was more than the value in the 0.99, 0.95 and 0.90 probability columns, indicating a significant difference between the proportion of rucks and mauls won by winners and losers.

Winners managed to turn over the opposition's possession by winning their rucks and mauls or by preventing release and hence being awarded the scrum in nine of the ten matches. The winning side was only turned over 3 times in one ten minute interval, the other instances of turnovers were only once or twice. In any ten minute interval losers were turned over 3 times on 3 occasions but also 4 times twice and once on 5 occasions. Overall winners were turned over about a third less than losers. Only during one ten minute interval did they concede possession over 10 times. In the first forty minutes winners only got turned over 14 times. Losers on the other hand were turned over 25 times. The values in this instance were regularly less than five and therefore the chi-square was not appropriate.

Winners conceded less penalties and free kicks in eight of the ten matches. In total the penalty/free-kicks conceded count was 118 by the winners and 156 by the losers. The null hypothesis is that there is no significant difference in the number of penalties and free-kicks conceded between winners and losers. The chi square value for the number of penalties and free-kicks conceded by winners and losers was 11.096, and at the appropriate degree of freedom value, this was more than the value in the 0.99, 0.95 and 0.90 probability columns, indicating again that there is a significant difference between the number of penalties and free-kicks conceded by winners and losers.

The division of the match into ten minute segments was a big step forward in the modelling of winning performance since it enabled the researcher to scrutinise the games at micro-situational level. There was clear evidence within this investigation that winners portrayed a different pattern of play from losers within the different time intervals of a match.

4.2.14 The Chaotic Pattern

Chaos theory suggests that an order exists within any random event. A chaotic and random pattern of events could well reflect a higher order of more complex occurrences. This investigation is an initial attempt at discovering whether such a pattern exists in a highly complex, interacting invasive game. The example presented here is the number of rucks and mauls won by winning and losing teams in the Five Nations' Championship 1996 and score differences. The results are examined in ten minute intervals in an iterative procedure.

Firstly the relationship between the number of rucks and mauls won by winners and the score difference was examined. The marginal values for each of the variables was computed. This was done by subtracting the previous result from the next one, that is, subtracting the number of rucks and mauls won in the first ten minutes from the number of rucks and mauls won. The sum and subsequently the mean of each marginal value were calculated and these were then subtracted from the marginal differences. The velocity of the limit cycle was calculated by multiplying the two variables together at each of the ten minute intervals.

The next step was to illustrate both the limit cycles and the velocity histories of both variables through a simple plot. These are shown in Figures 12 and 13 . The logical progression from this was to investigate and to calculate and plot the limit cycles and velocity histories for the losers in terms of rucks and mauls won (Figures 14 and 15) and then for each country (Figures 16 to 25).

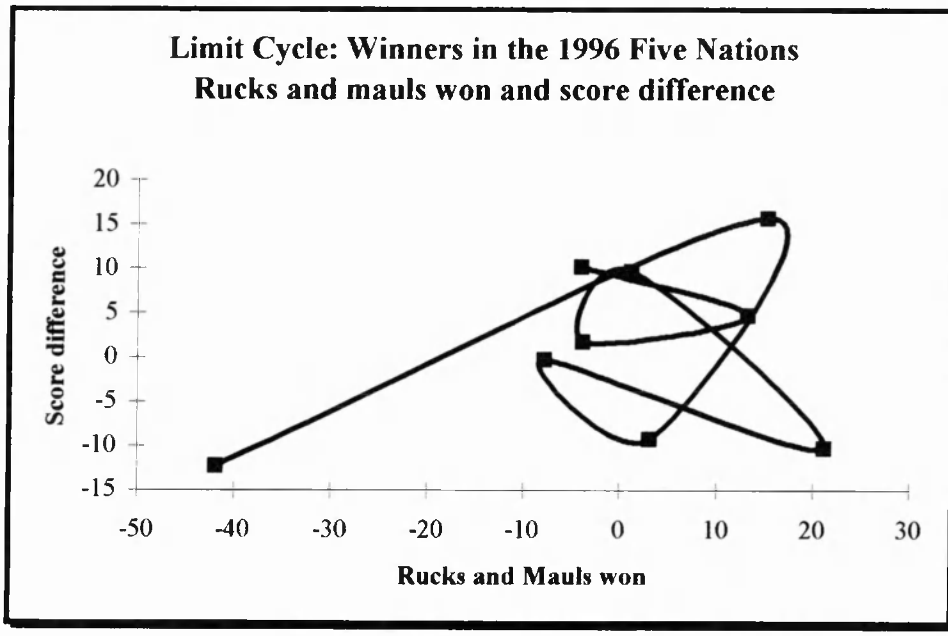

Figure 12: Limit cycle of rucks/mauls won by winners (1996 Five Nations' Tournament)

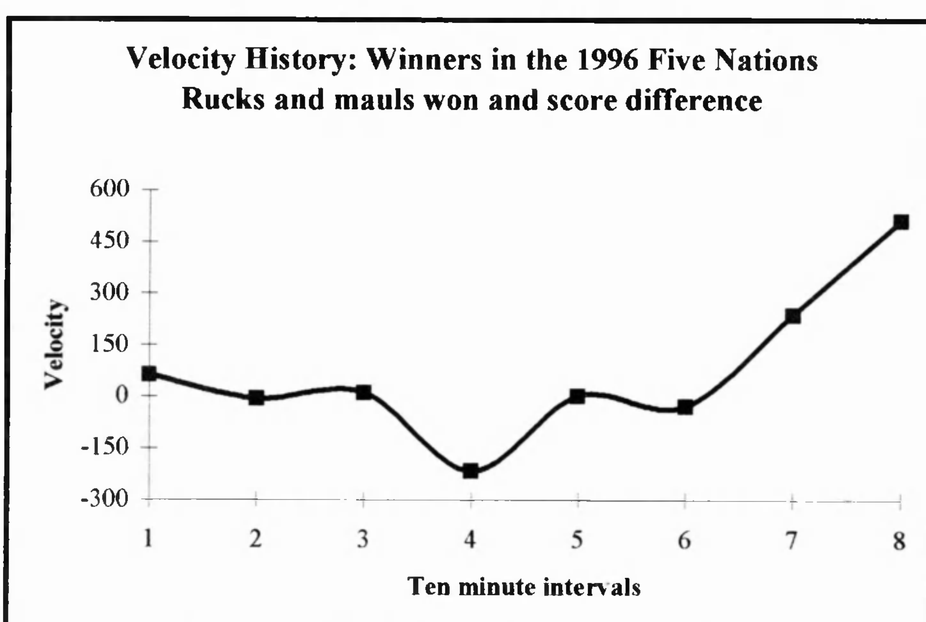

Figure 13: Velocity history of rucks/mauls won by winners (1996 Five Nations' Tournament)

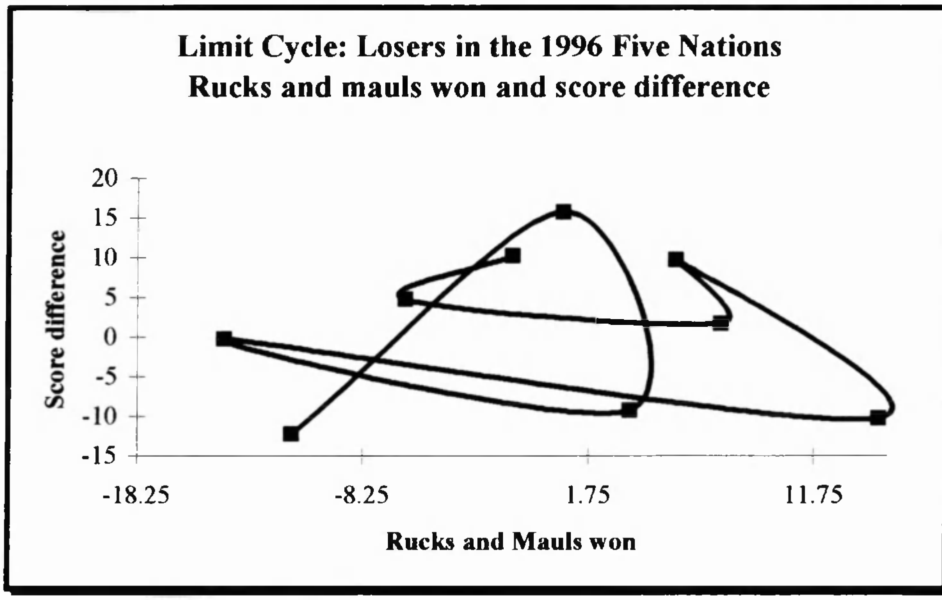

Figure 14: Limit cycle of rucks/mauls won by losers (1996 Five Nations' Tournament)

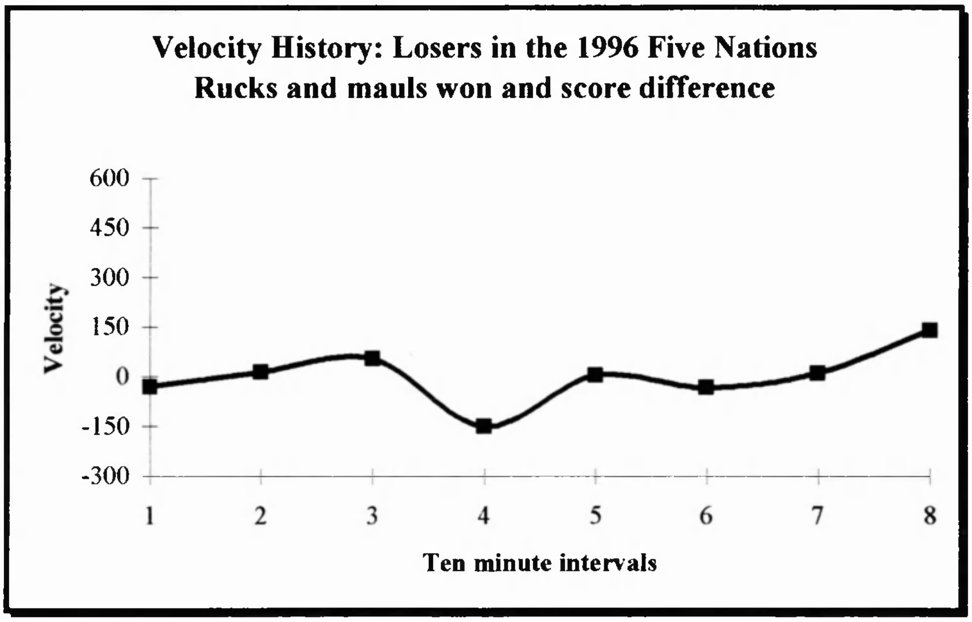

Figure 15: Velocity history of rucks/mauls won by losers (1996 Five Nations' Tournament)

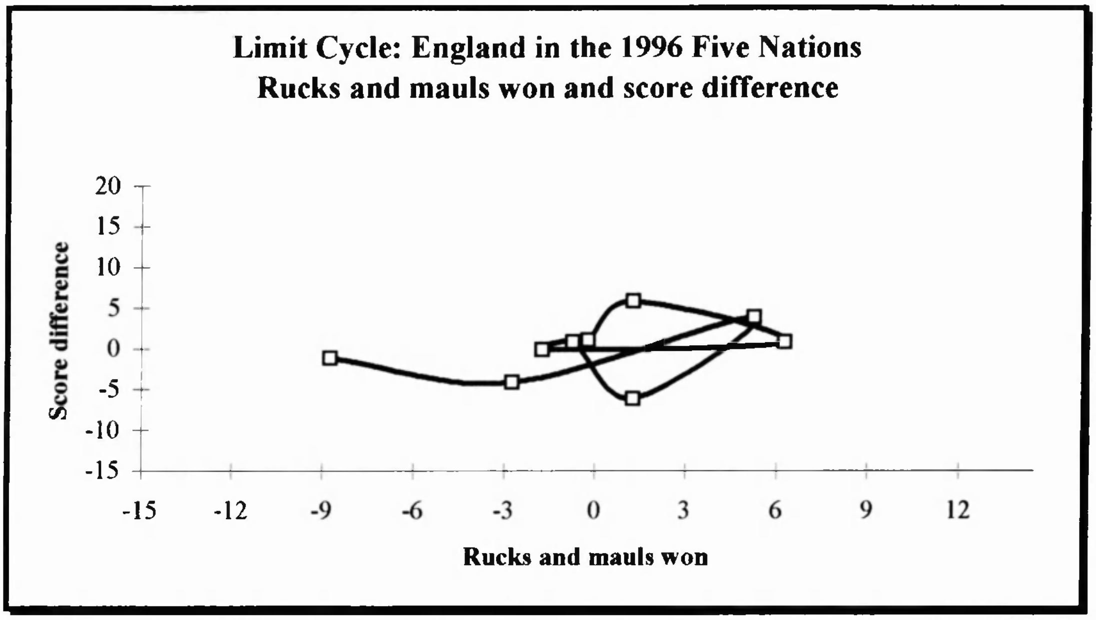

Figure 16: Limit cycle of rucks/mauls won by England (1996 Five Nations' Tournament)

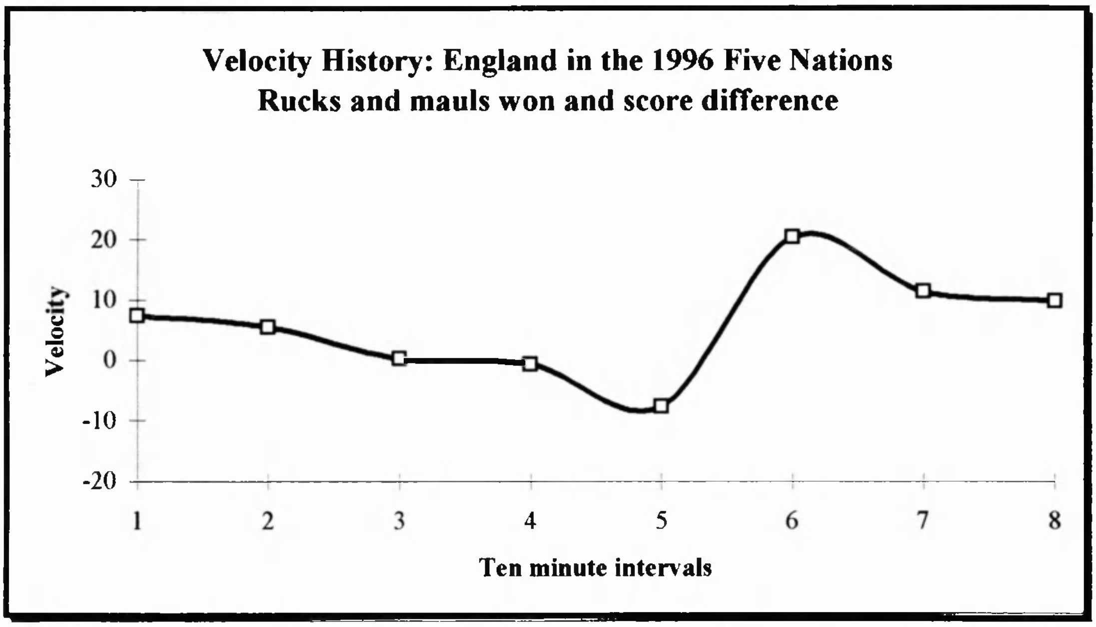

Figure 17: Velocity history of rucks/mauls won by England (1996 Five Nations' Tournament)

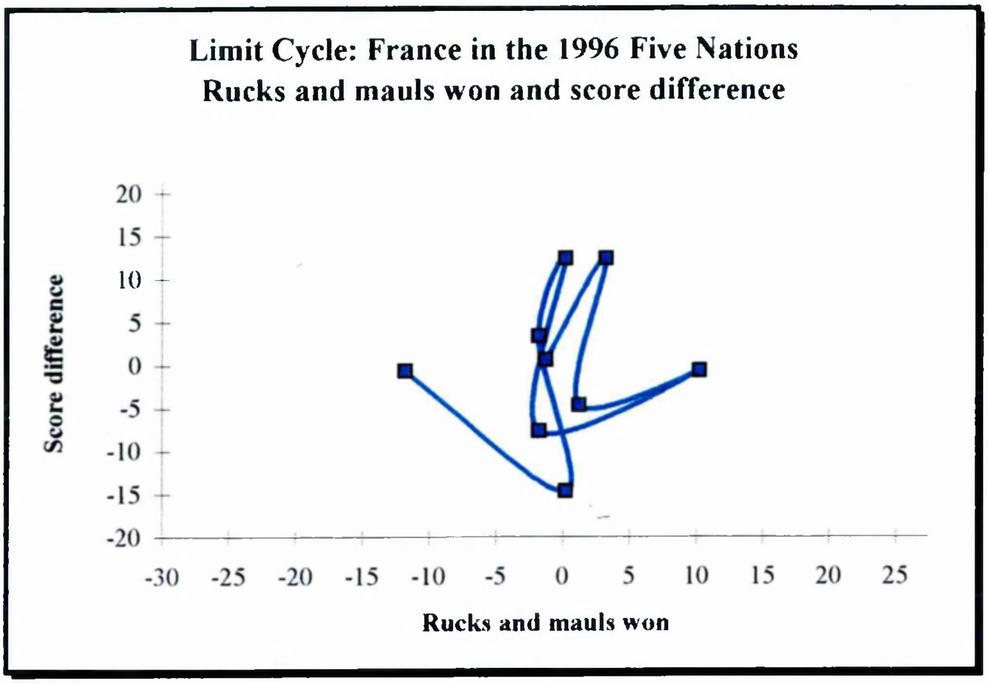

Figure 18: Limit cycle of rucks/mauls won by France (1996 Five Nations' Tournament)

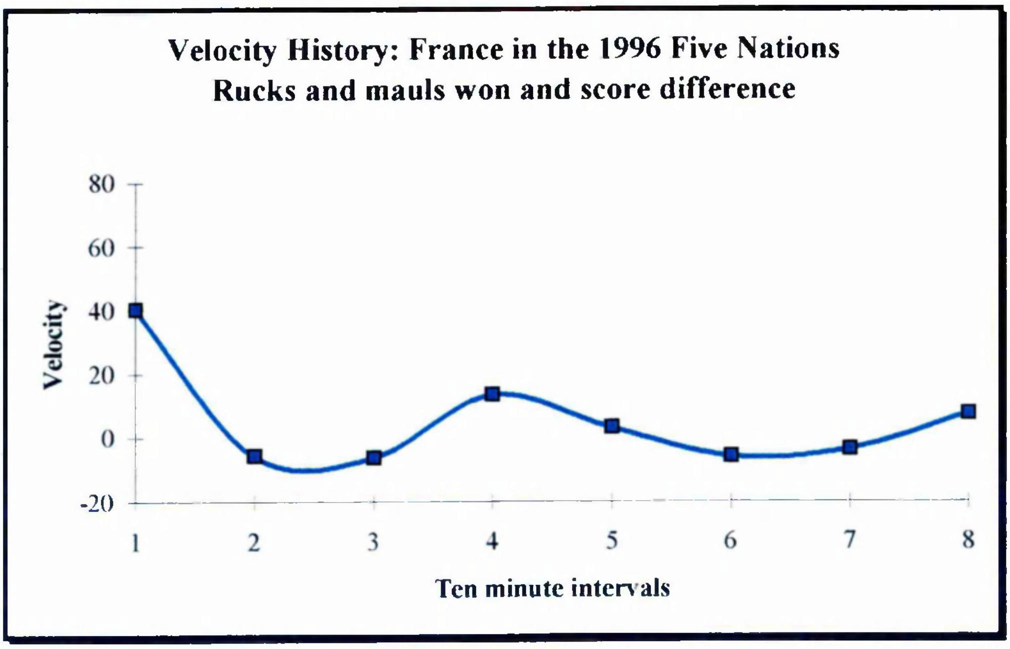

Figure 19: Velocity history of rucks/mauls won by France (1996 Five Nations' Tournament)

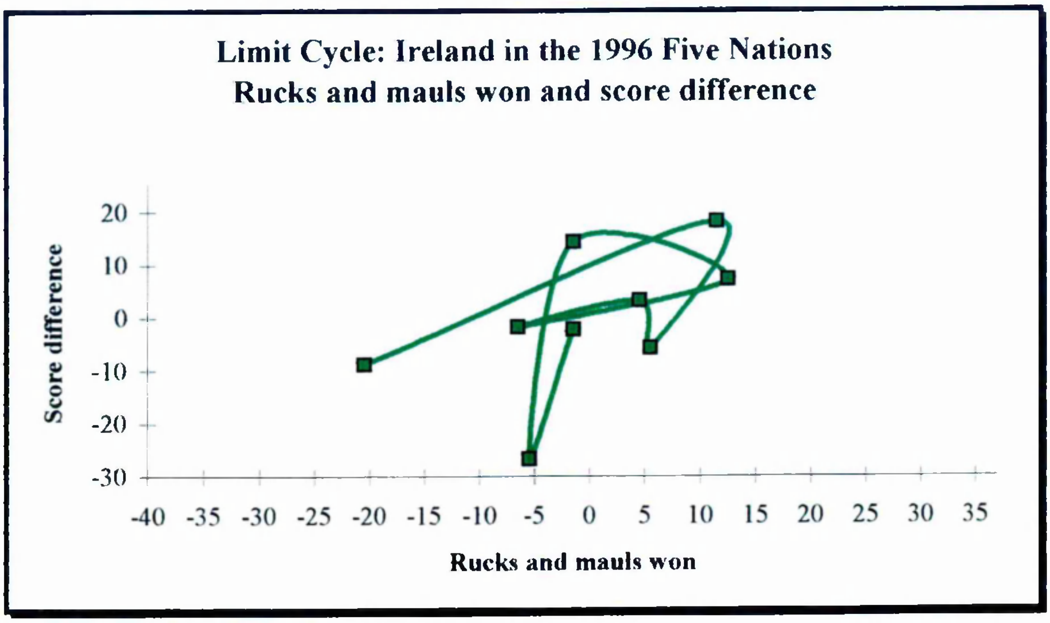

Figure 20: Limit cycle of rucks/mauls won by Ireland (1996 Five Nations' Tournament)

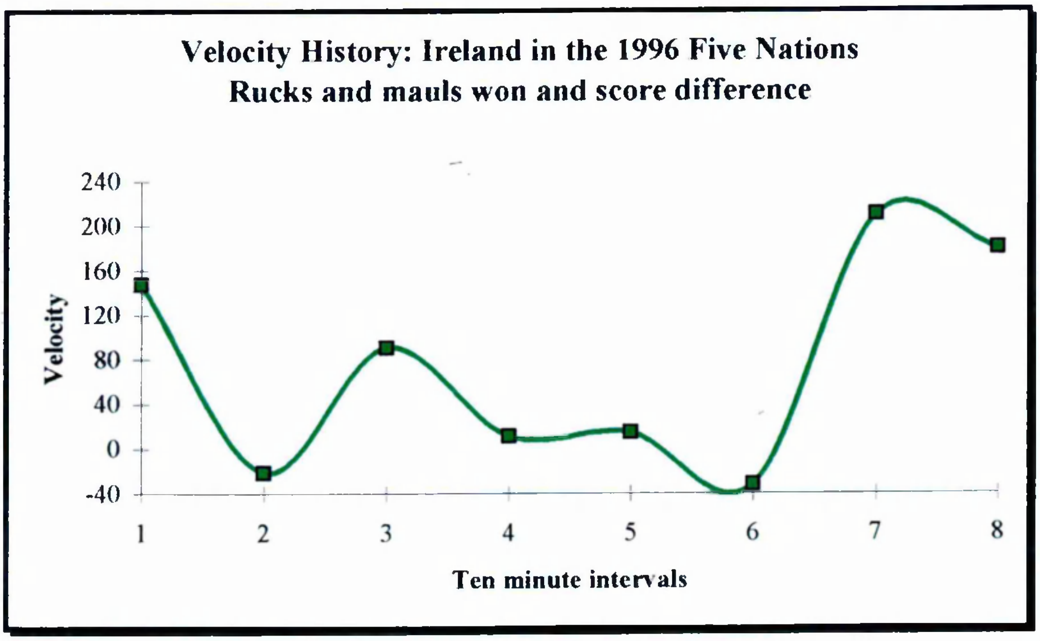

Figure 21: Velocity history of rucks/mauls won by Ireland (1996 Five Nations' Tournament)

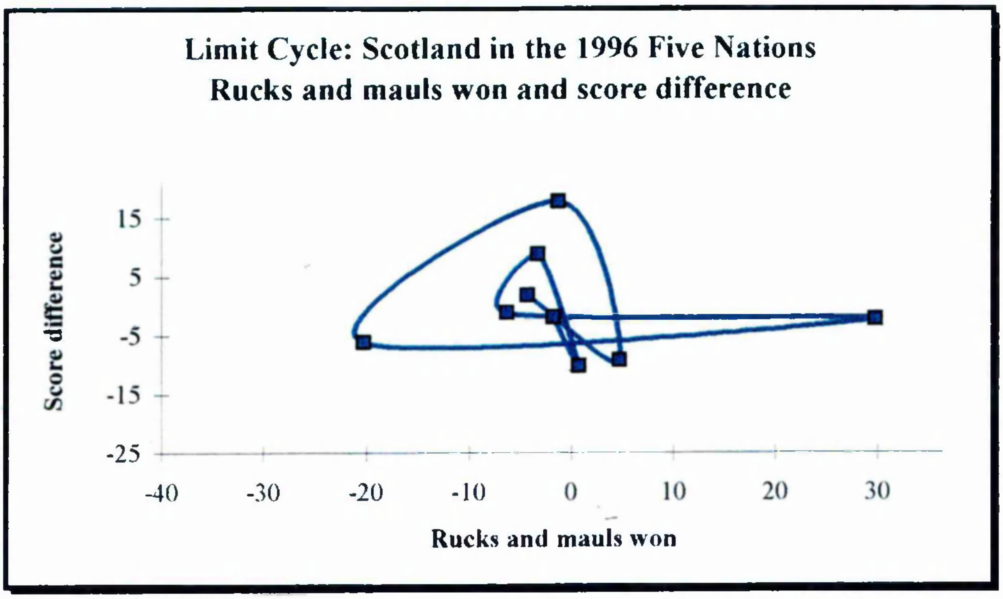

Figure 22: Limit cycle of rucks/mauls won by Scotland (1996 Five Nations' Tournament)

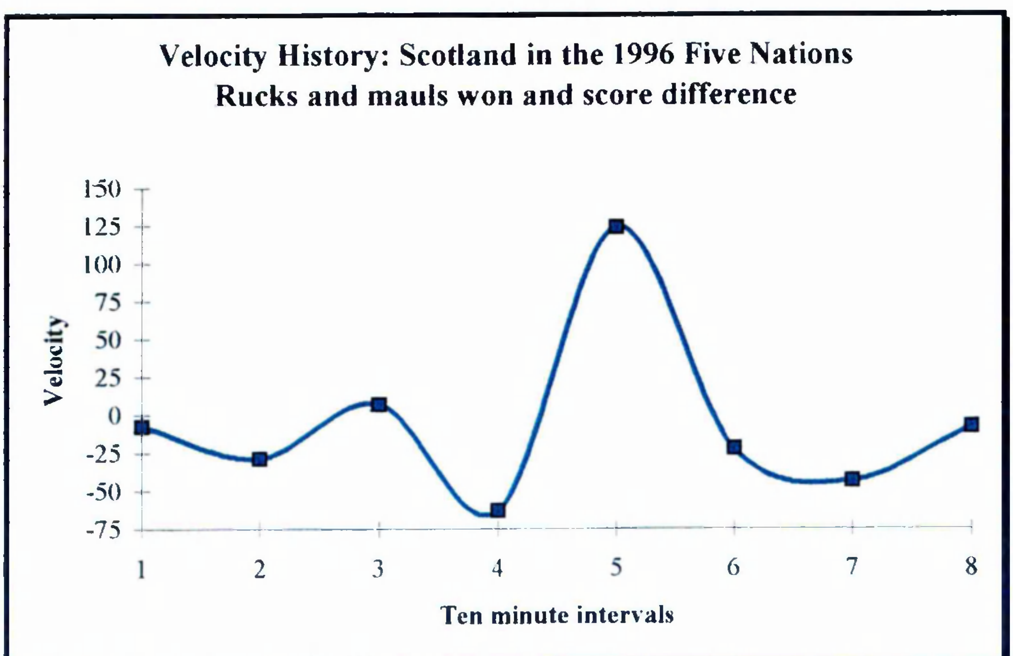

Figure 23: Velocity history of rucks/mauls won by Scotland (1996 Five Nations' Tournament)

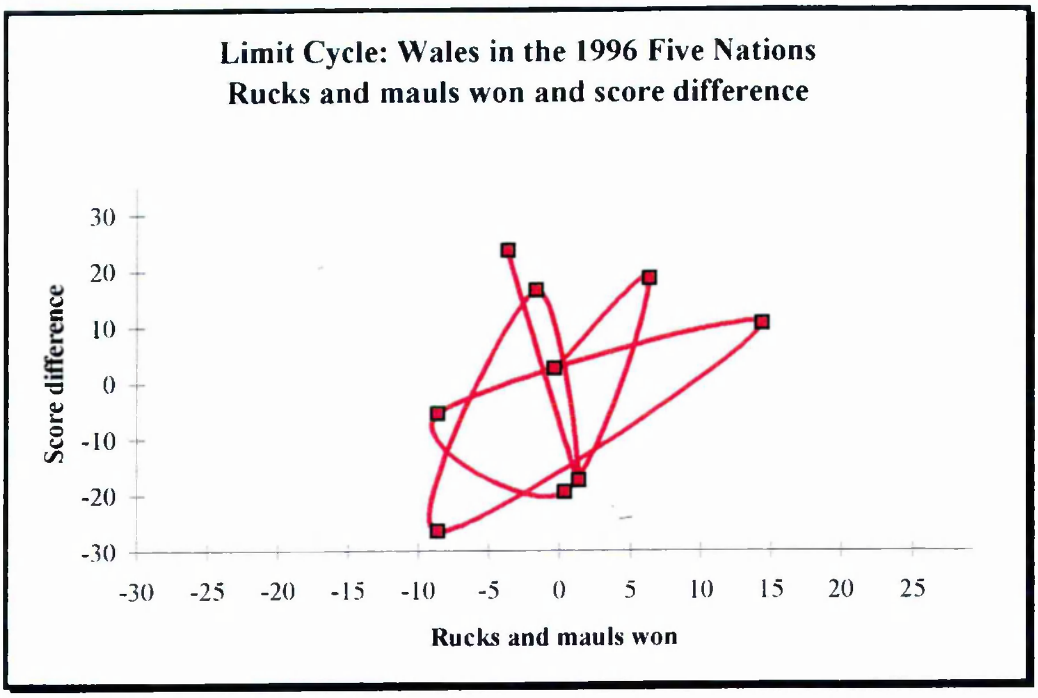

Figure 24: Limit cycle of rucks/mauls won by Wales (1996 Five Nations' Tournament)

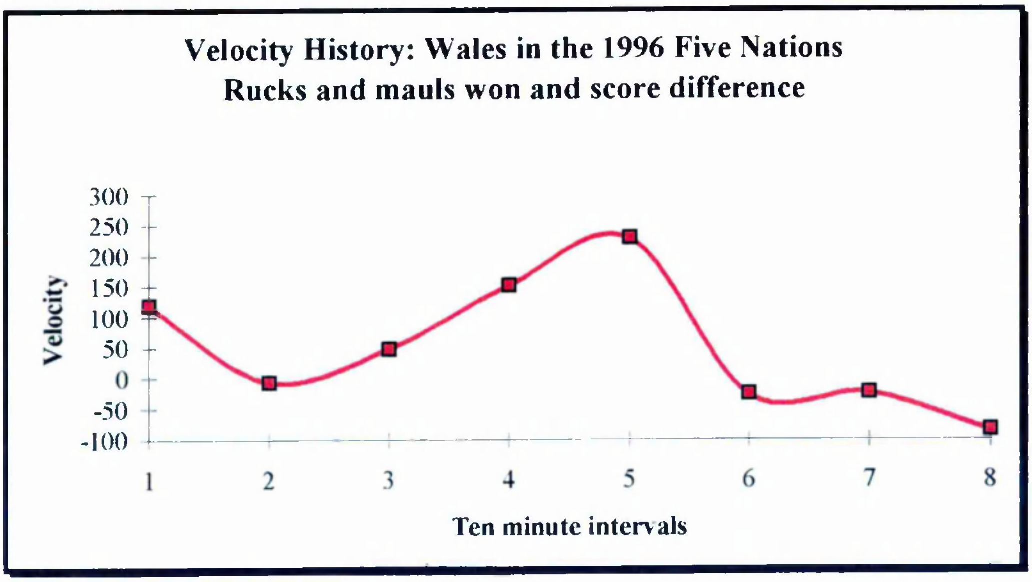

Figure 25: Velocity history of rucks/mauls won by Wales (1996 Five Nations' Tournament)

Priesmeyer and Baik (1989), whose formulas were used in this investigation, illustrated the limit cycles and velocity histories that one would associate with chaotic behaviour. The limit cycles which exemplified chaos were butterfly-patterned. They found that companies exhibited limit cycles which were identifiable as period one, two, three, or four, with period one companies viewed as the most stable and period four companies closest towards a chaotic state.

The limit cycles and velocity histories of England and France suggest a stable pattern whereas those of the Celtic nations - Ireland, Scotland and Wales tend more towards a chaotic pattern. However it is hard to compare the figures since the scaling requirements suggested in Priesmeyer and Baik (1989) meant that each of the five countries figures were scaled differently.

As a preliminary step in this investigation it was decided to plot the five velocity histories on one graph to enable a comparison to be made. The velocity histories shown in Figure 26 illustrate the change in the number of rucks and mauls won and the score difference between each ten minute interval. The trend suggested earlier is now far stronger. The difference in the velocity history of the two successful sides - England and France - are far more stable than the disorderly ones of the other three countries.

This investigation was too provisional to make conclusions that teams demonstrating stable patterns were more successful than those leaning towards chaotic environments. Other variables would have to be looked at and over longer periods of time, but as an

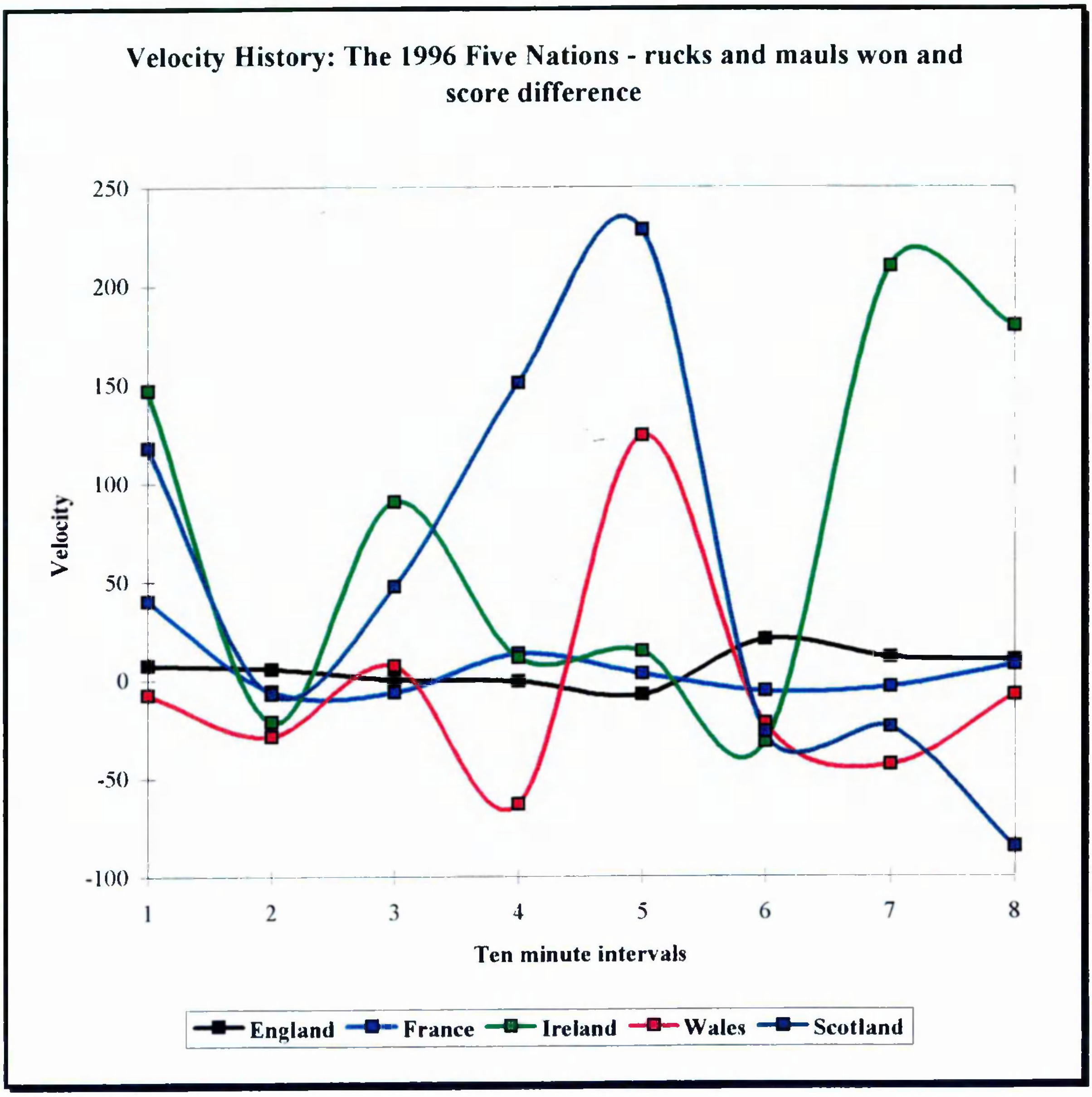

Figure 26: Velocity history of ruck/maul won for the five countries (1996 Five Nations' Tournament)

4.2.15 Individual Member Competence and Team Productivity

This investigation examined the importance of an individual's capabilities in maximising the total team effort. Bass and Ryterband (1978) stated:

> A team will be more effective if its individual members are capable, skilful, and knowledgeable about what needs to be done. The success of the group effort will also depend on how much and how well the group's members interact with each other.

England were unbeaten in the 1996 Five Nations' tournament and took the Grand Slam title. Together with France, they had been the dominant force within the Five Nations' Championship throughout the decade. They appeared to have built an environment in which like-minded individuals worked well together. There was an absence of diverse attitudes and this promoted an efficient as opposed to a creative pattern of play. Among Bass's (1980) recommendations to promote an efficient as opposed to inefficient environment were that members had the necessary skills, were taught by experts, could all work as a team for a common purpose and were motivated. The English team had encouraged a pattern of self-discipline within their play, one which was dependent upon every individual performing to their standards. They had a pattern of play in which they optimised their individual talents for the total effect.

The English team remained the same for all four matches in the Championship, and only three replacements were used, all of these in the final match against Scotland. Marriot (1949) and Worthy (1950) had concluded that team productivity increased in smaller groups and by keeping the number of players used to a minimum the chances of team product being greater were increased. The ability of all members of the England team to remain injury-free throughout the Championship is indicative of a high level of fitness, a strong mental attitude and also of a high level of confidence of the coaches and selectors in the abilities of the individuals. As posited by Bass (1980), the bio-data or make-up of the individuals were well suited to the high intensity of the Five Nations' tournament.

Bass (1980) suggested three conditions under which team productivity could be enhanced. It could be bettered the more capable the average member was, the more interdependence of each member and also if the "slowest link in the chain" was better. From the tackle count figures it is evident that each individual is involved. In the high tackling match against Ireland all the players in the fulcrum of the action had high work rates, but also the second-rowers and front-rowers are making a high number of tackles. The average member here is helping to maximise the whole team effort. Additionally, the "slowest link in the chain" or the perceived weak link is heavily involved. Martin Bayfield, at 6ft 10ins maybe considered by many as solely a line-out threat. However, he averaged four tackles per match and as many as eight in a high tackling match. In terms of penalties conceded, Martin Johnson was the weak link. He conceded a total of 12 penalties at an average of 3 per match. This was a problem for England and if they had managed to minimise Johnson's penalties the team as a whole would be close to conceding single figure penalties per match. The individuals generally conceded either nil or one penalties per match and the same amount of errors. The weak link in terms of errors was the scrum-half, Kyran Bracken, who made a total of nine at an average of just over two per match. This though is not very high considering the number of touches he gets in the course of a match.

Graham and Dillon (1974) concluded that "super-groups" composed of individually productive people did well to enhance team productivity. This is illustrated in the English tackling data. Their back-row, half-back and centre units could be considered as super-groups. Each of the back-row unit totalled between thirty seven and forty tackles per match, both half-backs totalled over twenty six tackles and the centres both made in excess of twenty tackles. In their mobility the English forwards had four players who exceeded the hundred score, while in terms of errors two of the back-row players did not make one error in the four matches, the centre only made three between them and at outside-half, Andrew only averaged one error per match. In forcing errors the English back-row pressured the opposition into an average of four errors per match, as did the half-backs.

Ronan (1963) took it a step further and suggested that in addition to "super-groups" that certain members within a team who had an important role needed to be strong and influential members. In a rugby union side a team has a backbone which to better team performance needs to consist of strong members in the number eight, second row, hooker and half-back positions. These are traditionally the decision makers of a side. With the England team they were exceptionally strong in these areas with very efficient players making large contributions:

Dean Richards at Number Eight	Martin Johnson in the Second Row
Brian Moore at Hooker	Rob Andrew at Outside Half

In the tackling count, Dean Richards made an average of ten tackles per match nine of which were successful, Johnson made a total of twenty four successful hits from 26 tackles, Moore twelve from only thirteen and Andrew an average of six successes from seven hits. Richards and Johnson were also exceptionally adept in their mobility, with Johnson achieving scores approaching those of the back-row and Richards always at the top of the statistics. Among Bass' (1980) conclusions were that teams needed at least one member with above average capabilities. The figures for Dean Richards shown above clearly identify him as an exceptional member of the side.

Bass (1980) asks if the total effect will be maximised if the team consists of an army of rabbits led by a lion or an army of lions led by a rabbit. It has already been shown that the English team consisted of very capable individuals but in addition they had the benefit of being led by a captain who was also strong. Will Carling's statistics exhibited this:

1. Twenty seven successful tackles from a possible twenty eight (average of 7 from 7 per match).
2. Only two penalties conceded in the four matches.
3. Only two errors made in the four matches.
4. Four errors made by the opposition due to pressure exerted by Carling, average of one error per match.

The final point is that for a team to maximise its productivity it needs the ability to increase its status and esteem, influence and ability through promotional packages, training, and feedback (Bass (1980). The English team at this period were particularly well-supported by the off-field structure that surrounded it.

4.3 Association Football

Data are presented and discussed here in a similar fashion to **4.2**.

4.3.1 Game Content

The twenty matches of the 1996 European Championship tournament that were analysed produced an average of over 55 minutes ball in play time per match, and within this time a total of 37 goals were scored. The match time figures vary from one minute and forty seven seconds of injury time to six minutes and fifty seconds. The amount of extra-time played due to stoppages appears to be more accurate than in the past when barely any stoppage time was played. It also appears more accurate than some of the rugby matches analysed. The ball in play figures vary from a low 48 minutes and 46 seconds to a high of 60 minutes and 18 seconds. The number of activity cycles was quite variable and ranged from a minimum figure of 102 to a maximum of 140. The mean number of cycles was approximately 118. The variability is significantly more than in rugby union matches and the overall figure is also higher.

Table 22: Global figures for Euro '96

Variable	Total	Minimum	Maximum	Mean
Match time	1879m 54s	91m 47s	96m 50s	94m 00s
Ball in Play	1101m 38s	48m 46s	60m 18s	55m 05s
Activity Cycles	2354	102	140	118
Throw-ins	815	24	53	41
GK Possessions	840	34	57	42
FK/Penalties	832	27	55	42
Passes	16252	683	943	813
Attacking Plays	1507	60	106	76
Goals	37	0	5	2

The three areas which one could consider as set-piece areas i.e. throw-ins, goal-keeper possessions and free-kick situations are within close proximity to each other and are also comparable with the figures for line-out and scrum situations in rugby union in terms of mean figures and maximum and minimum figures. The number of attempted passes were within a range of 683 and 943, with a mean of 813. The minimum and maximum for attacking strikes, that is, crosses, corners, shots and headers were 60 and 106 respectively.

The individual match frequencies (Table 23) illustrated little pattern within the figures in terms of some of the variables, for example, passes, free-kicks, attacking strikes. In some of the other variables however there were certain similarities. Three of Croatia's matches involved three goals - above the average; three of the matches involving Portugal were much longer than the mean match times; England's four matches were all below the mean figure for activity cycles and two were very close to dipping below 100; three of Germany's matches were much higher than the mean in terms of number of throw-ins, two being in excess of fifty.

Table 23: Individual match frequencies for Euro '96

Match	Goals	Match Time	Ball in Play	Activity Cycles	Throw Ins	GK Possess	Passes	FK / Pens	Attack Strikes
Denmark v Portugal	2	95m 25s	60m 06s	104	24	41	933	46	88
Spain v Bulgaria	2	95m 29s	48m 46s	140	44	34	719	50	106
France v Romania	1	93m 33s	56m 44s	126	44	47	809	51	70
Turkey v Croatia	1	94m 44s	52m 51s	125	45	50	707	44	60
Italy v Russia	3	93m 01s	54m 44s	120	37	38	939	45	73
Switzerland v Holland	2	93m 11s	49m 54s	119	41	42	717	39	92
Portugal v Turkey	1	96m 00s	56m 18s	114	33	41	854	49	73
England v Scotland	2	92m 17s	49m 30s	114	36	43	706	41	71
Croatia v Denmark	3	95m 43s	56m 47s	107	37	57	786	32	75
France v Bulgaria	4	95m 30s	55m 17s	125	46	36	832	52	65
England v Holland	5	93m 16s	54m 37s	111	38	43	819	28	81
Germany v Italy	0	92m 48s	55m 41s	136	53	36	884	50	71
Croatia v Portugal	3	93m 23s	58m 36s	116	44	36	943	34	77
Germany v Croatia	3	94m 22s	51m 57s	123	40	46	683	44	69
France v Holland	0	93m 47s	56m 47s	108	38	46	847	38	69
Spain v England	0	91m 47s	57m 59s	105	44	41	826	27	79
Portugal v Czech Rep	1	96m 50s	55m 11s	123	30	38	792	55	71
France v Czech Rep	0	93m 21s	60m 18s	114	42	49	890	42	63
England v Germany	2	91m 53s	56m 25s	102	46	35	871	33	84
Germany v Czech Rep	2	93m 32s	53m 10s	122	53	41	695	32	70

The thirty three matches of the 1994 World Cup tournament that were analysed produced an average of over 58 minutes 30 seconds ball in play time per match, and within this time a total of 84 goals were scored. The match time figures vary from fifty three seconds of injury time to thirteen minutes and forty nine seconds. The amount of extra-time played due to stoppages appears to be more accurate than in the past when barely any stoppage time was played. It also appears more accurate than some of the rugby matches analysed. The ball in play figures vary from a low 46 minutes and 56 seconds to a high of 66 minutes and 47 seconds.

Table 24: Global figures for 1994 World Cup

Variable	Total	Minimum	Maximum	Mean
Match time	3117m 29s	90m 53s	103m 49s	94m 28s
Ball in Play	1932m 16s	46m 56s	66m 47s	58m 33s
Throw-ins	1342	22	52	41
Corners	314	4	19	10
Goal Kicks	639	10	32	19
FK/Penalties	1214	20	50	37
Passes made	23531	567	916	713
Shots	908	18	40	28
Goals	84	0	5	3

The three areas which one could consider as set-piece areas, that is, throw-ins, goal-kicks, and free-kick situations are within close proximity to each other and are also comparable with the figures for line-out and scrum situations in rugby union in terms of mean figures and maximum and minimum figures. On average there are 10 corners in each match. The number of passes made were within a range of 567 and 916, with a mean of 713. The minimum and maximum for shots and headers at goal were 18 and 40 respectively.

The individual match frequencies (Table 25) illustrated that there are certain patterns evident within the figures in terms of some of the variables.

Table 25: Individual match frequencies for 1994 World Cup

Match	Goals	Match Time	Ball in Play	Throw Ins	Corners	Goal Kicks	Passes Made	FK / Pens	Shots Made
Germany v Bolivia	1	93m 00s	58m 15s	35	8	18	678	36	19
Spain v South Korea	4	92m 36s	55m 11s	42	12	19	645	32	29
USA v Switzerland	2	91m 42s	56m 54s	50	10	23	640	28	30
Columbia v Romania	4	93m 39s	55m 23s	37	13	14	781	43	29
Cameroon v Sweden	4	92m 45s	57m 23s	42	7	24	701	28	25
Brazil v Russia	2	93m 05s	58m 31s	41	9	17	792	27	27
Holland v S Arabia	3	93m 48s	55m 51s	40	12	18	668	33	38
Argentina v Greece	4	95m 00s	59m 49s	42	6	20	796	40	27
Germany v Spain	2	92m 34s	56m 46s	54	11	15	674	37	23
Nigeria v Bulgaria	3	97m 15s	57m 36s	42	15	16	624	31	22
USA v Columbia	3	93m 10s	62m 27s	42	11	18	802	29	34
Italy v Norway	1	95m 04s	56m 34s	45	10	10	669	50	20
S Korea v Bolivia	0	103m49s	60m 58s	43	8	32	656	45	38
Mexico v Ireland	3	94m 07s	56m 36s	59	5	23	643	34	21
Brazil v Cameroon	3	94m 48s	58m 20s	46	8	18	723	39	18
Sweden v Russia	4	96m 42s	61m 01s	50	5	20	733	37	33
Belgium v Holland	1	94m 49s	60m 50s	22	10	29	751	44	35
Argentina v Nigeria	3	96m 59s	58m 09s	24	8	22	761	42	27
Germany v S Korea	5	95m 22s	57m 02s	33	10	23	684	37	33
Ireland v Norway	0	93m 37s	58m 17s	52	10	15	578	40	18
Brazil v Sweden	2	92m 46s	66m 47s	34	6	23	916	25	28
Argentina v Bulgaria	2	95m 33s	57m 37s	45	9	14	724	45	22
Germany v Belgium	5	95m 44s	58m 57s	36	19	29	729	36	35
Spain v Switzerland	3	91m 21s	46m 56s	43	15	21	567	46	32
S Arabia v Sweden	4	94m 06s	63m 02s	33	10	23	740	20	40
Argentina v Romania	5	93m 55s	56m 30s	31	9	18	669	44	34
Ireland v Holland	2	95m 18s	55m 59s	38	14	25	709	35	34
Brazil v USA	1	94m 44s	56m 45s	47	14	13	638	32	20
Nigeria v Italy	2	93m 41s	59m 51s	41	6	13	692	42	26
Mexico v Bulgaria	2	98m 31s	56m 40s	39	11	13	692	38	27
Bulgaria v Italy	3	94m 12s	62m 04s	47	4	17	746	48	20
Sweden v Brazil	1	92m 54s	65m 46s	33	4	20	854	34	26
Italy v Brazil	0	90m 53s	63m 29s	34	5	16	856	37	18

In terms of ball in play time, Brazil and Sweden are regularly involved in high action matches. Brazil on three occasion are both above the average figure and also above the sixty minute threshold and Sweden four times above both the average and the sixty minutes. Brazil are the only country which is involved in three matches which have over 850 passes completed in each match.

Argentina are regularly involved in matches with a high number of free-kicks and penalties awarded. Three of their matches have over 45 free-kicks and penalties. Finally, Holland are often in matches with a high number of shots on goal - against Saudi Arabia (38 shots), Belgium (35 shots), Ireland (34 shots).

Such game content data are intended to provide a backcloth to winning performance and to provide a context for subsequent investigations.

4.3.2 Match Officials

Match officials in Euro '96 worked in groups of three. All the officials for any particular match came from the same country. There were no officials involved from any country outside Europe. A country was represented by one referee and he was assisted by two linesmen (assistant referees).

Overall, there was little evidence of the referee having a bearing on the end result. This is not a counter predictive finding. Whilst it would be possible for a referee to have a direct impact on the result of a game, the opportunity to do so is less than in rugby union. In a tournament such as the European Championship, all the referees come under one umbrella body (UEFA) and are all senior, experienced officials. It is more likely that major differences in refereeing performance would occur, if at all, within a world tournament where referees would come from a much greater range of countries with very different backgrounds and levels of experience.

The referees for the 33 matches from the 1994 World Cup were noted. Twenty one referees' matches were analysed. Nine officials refereed more than one match but only one official refereed the same country twice. Sandor Puhl from Hungary officiated Brazil twice and they drew twice. It was impossible to draw any conclusions from this. In contrast to the findings in rugby union, referees did not appear to have a direct impact on a game's outcome. This is not to suggest that decisions across games in the World Cup were totally consistent. The governing body (FIFA) established strict guidelines for referee performance and monitored these throughout the tournament. Appointments to referee the knockout phase of the tournament were made in relation to a referee's performance in the pool games. Conformity to a central standard was thus rewarded by further appointments.

4.3.3 Home-ground Advantage

Countries pre-qualify for the European Soccer Championship. One country hosts the tournament every four years. Euro '96 was played in England during the month of June, 1996. The home-ground advantage applied to only one side, England. Four matches were analysed involving England. They won two of the matches and drew the other two. They lost to Germany in extra-time in the fourth match. It would seem fair to assume that their knowledge of the home conditions plus the effect of the crowd size, density and support was invaluable to them. Two of the matches resulted in a home win for England and two matches ended in a draw after normal time. Overall the home side scored 7 goals (78%) and conceded two goals.

Table 26: Home Team's Data for Euro '96

Match	Home Win	Territorial Dominance	Times in Opp PA	Time in Possession	FK/Pens Awarded
England v Scotland	Yes (100%)	42m 15s (46%)	37 (51%)	24m 00s (48%)	20 (49%)
England v Holland	Yes (80%)	42m 05s (45%)	30 (34%)	25m 21s (46%)	11 (39%)
Spain v England	Draw (50%)	45m 58s (50%)	37 (40%)	30m 26s (52%)	13 (48%)
England v Germany	Draw (50%)	54m 46s (60%)	44 (61%)	31m 07s (55%)	15 (45%)

The home side had greater territorial dominance in one of the matches (v Germany) and parity in a second match (v Spain). A similar pattern is evident in the number of times that the home side had entries into the opposition penalty area. The home side had a greater number in two of the matches, although one of these was very close to parity. Another indicator of sustained pressure is the time that the team can keep control of the ball. This is shown in the time in possession figures, with the percentage figure indicating their share as opposed to the opposition (that is, only ball in play time excluding ball in air is considered). Here the home side had control of the ball more than the opposition in two matches. The number of free-kicks and penalties is a further indicator of pressure exerted on the opposition. It may also indicate the pressure exerted on the referee by overwhelming home support. The home side were not awarded more free-kicks and penalties on any of the four occasions.

Although the data set is small there does not seem to be any clear indications that home ground advantage is a key factor in the end result. The home side did not enjoy dominance in pressure variables that are associated with home ground advantage. This is unlike the results of the rugby data.

The World Cup is also a quadrennial tournament for which countries pre-qualify. In 1994 the hosts were the United States of America and games were played during the months of June and July. The home-ground advantage applied to only one side, the United States of America. Only two matches were analysed involving the USA. They won one of the matches and drew the other one. The home side scored 3 goals (60%) and conceded two. The number of free-kicks and penalties could be considered as an indicator of pressure exerted on the opposition resulting in free-kicks being conceded. It may also indicate the pressure exerted on the referee by overwhelming home support. The home side were awarded more free-kicks in one game and the same amount in the other game.

Table 27: Home Team's Data for USA '94

Match	Home Win	Free-Kicks Awarded
USA v Switzerland	Draw (50%)	14 (50%)
USA v Columbia	Yes (67%)	10 (35%)

The data collected did not illustrate home-ground advantage. The USA team qualified for the tournament as hosts and although they performed creditably their world ranking was such that their involvement in the knockout stages of the competition was improbable. Home-ground advantage appears to operate either over a longer period of time or where the team is highly ranked in a sport.

4.3.4 The First Score

The Euro '96 soccer tournament was analysed to identify the first team to score in a game. The research also examined whether the team that was in the lead at half-time won the match. The team that scored the first goal won on 12 of 16 occasions. The team that scored the first goal did not lose any match. In addition, the team that was in the lead at half won the match on 5 of 7 occasions. In the other matches the scores were level at half-time. The team that was not losing at half-time did not lose the match on 20 of 20 occasions. In summary, the probabilities are as follows:

Probability (Team scoring first goal wins)	=	3/4
Probability (Team leading at half-time wins)	=	5/7
Probability (Team scoring first and leading at half-time)	=	5/7

Thus, the probability that a team wins the match if:

They score first	=	3/8
They are leading at half-time	=	5/14
They score first and are leading at half-time	=	5/14

A similar investigation was undertaken for the 1994 World Cup. In this tournament, the team that scored the first goal won the match on 20 out of 33 occasions. The team that scored the first goal did not lose the match on 30 out of 33 occasions. In addition, the team that was in the lead at half won the match on 15 of 16 occasions. In the other matches the scores were level at half-time. The team that was not losing at half-time did not lose the match on 32 of 33 occasions. In summary, the probabilities are as follows:

Probability (Team scoring first goal wins)	=	20/33
Probability (Team leading at half-time wins)	=	15/16
Probability (Team scoring first and leading at half-time)	=	14/15

Thus, the probability that a team wins the match if:

They score first	=	10/33
They are leading at half-time	=	15/32
They score first and are leading at half-time	=	7/15

The importance of the first score on the bearing of the end result was very high in the data sets for both rugby union and association football.

This investigation proved very conclusive over all the data sets. The importance of scoring first and of being in the lead or at least of not losing at half-time had a direct relationship with the end result. There can never be 100% certainty in invasive games but the results show time and time again that these are decisive factors and are only overcome when one of the world's best teams concede an early goal and have to chase the game. That they can overcome this trend is an indication of their ability and status.

4.3.5 High Performance Ratings

In Euro '96 it is evident that there is little correlation between team's high performance ratings and their success. From Table 28 it is evident that Germany, the eventual winners of the tournament, are only present in two of the six categories and in these they are only in fourth and fifth positions. The Czech Republic, the eventual runners-up, only appear once more than the Germans. They are second once but fourth on the other two occasions. Romania, Denmark, Russia, Scotland and Italy all appear in the table and yet they did not progress to the knock-out stages. Portugal are the most prominent team, appearing seven times in the table and yet they were eliminated at the quarter-final stages. Out of the thirty positions in the high performance rankings only ten are filled by the four teams that reached the semi-final stages of the tournament.

Table 28: Top Five Performances in Euro '96

	Throw-ins Share (%)	**GK Passes Share (%)**	**Throw-ins Retained (%)**	**GK Passes Retained (%)**	**Attacking Success (%)**	**Territorial Advantage (%)**
1	Romania 73	Portugal 73	Holland 95	Spain 100	England 52	Italy 65
2	Portugal 67	Czech Rep 65	England 95	Russia 100	Croatia 44	France 61
3	Russia 65	Denmark 63	Portugal 95	Portugal 100	Spain 44	England 60
4	Portugal 63	England 63	Czech Rep 94	Germany 94	Czech Rep 43	Portugal 59
5	Germany 61	Holland 59	Scotland 94	Croatia 89	Scotland 43	Portugal 57

However, in the six key areas in the 1994 World Cup (Table 29) it is evident that there is a correlation between team's high ratings and their success in that tournament.

Table 29: Top Eight Performances in USA '94

	Throw-ins Share (%)	Goal Kicks Share (%)	Corners Share (%)	Passes Share (%)	Shooting Success (%)
1	Argentina (81)	Romania (89)	Brazil (100)	Holland (76)	Brazil (100)
2	Switzerland (70)	Sweden (85)	S Arabia (80) =	Brazil (76)	S Korea (100)
3	Cameroon (63)	Bolivia (78)	Russia (80) =	Brazil (70)	Brazil (86)
4	Ireland (63)	Nigeria (77)	Brazil (80) =	Columbia (70)	Brazil (83)
5	Holland (63)	Greece (75)	Switzerland (80)	Columbia (70)	Switzerland (80)=
6	Argentina (63)	Spain (71)	Brazil (78)	Brazil (66)	Holland (80)=
7	Brazil (60)	USA (69)	Germany (75) =	Brazil (64)	Italy (80)=
8	Bulgaria (60)	USA=Spain= S Arabia (67)	S Korea= Brazil=Argentina (75)	Argentina (64)	Brazil (80)

Brazil, the winners, are present in four of the five categories. They do not appear in the goal-kicks' share and only once in the throw-ins' share but in the other more attacking based variables they are very prominent. They appear four times in each of the three variables, twice in first position and second in the other. Countries do appear in the table that did not progress to the knock-out stages but these are predominantly within the throw-ins and goal-kicking shares. Of the sixteen positions within these two variables only three are filled by the four teams that reached the semi-final stages. In the other 24 positions Brazil fill twelve and Italy one but the other losing semi-finalists do not appear.

4.3.6 The Winning Range

In Euro '96 the expected patterns of larger maxima and minima for the winners and lower ones for the losers does appear to a certain extent. Losers only have higher minima than winners on 3 occasions and maxima on 4 occasions. The range for throw-ins awarded is at a higher level for losers, as is the rate of keeping possessions from the goal-keeper and territorial dominance. The areas where winners have a distinct advantage are at the retention of possession from the throw-ins, the total number of goal-keeper possessions, the success in shooting and overall attacking strikes (shots, corners, headers at goal and crosses), and the total number of passes attempted. In terms of discipline the losers conceded fewer free-kicks and penalties.

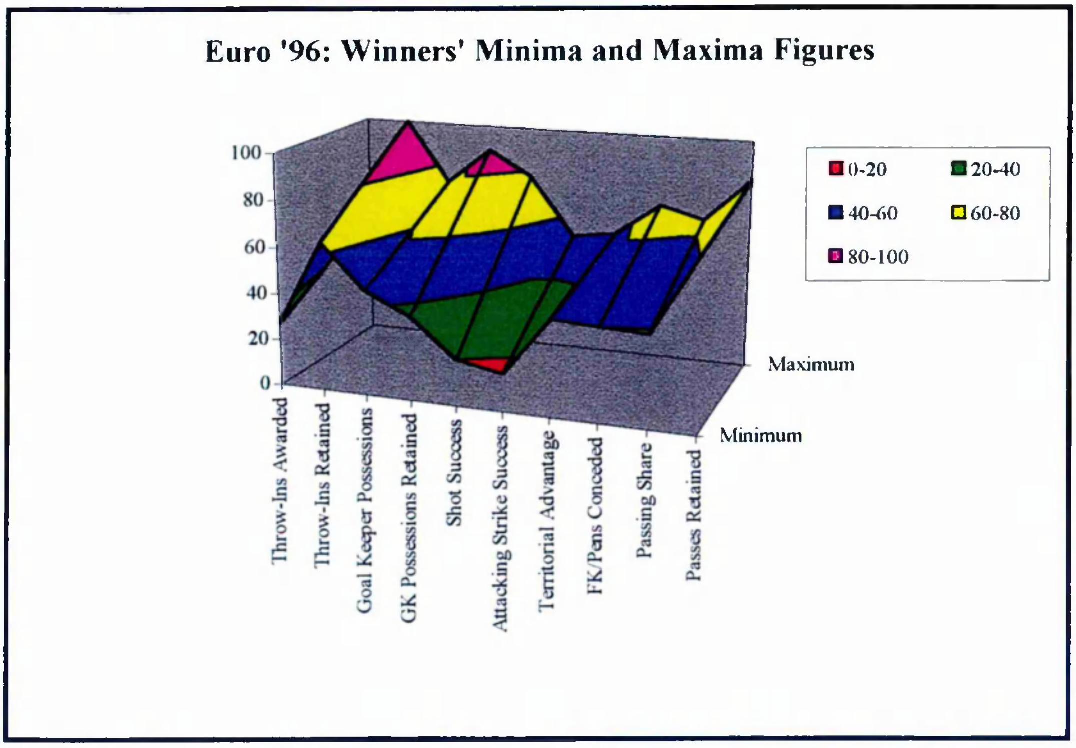

Figure 27: Winners' Minima and Maxima for Euro '96

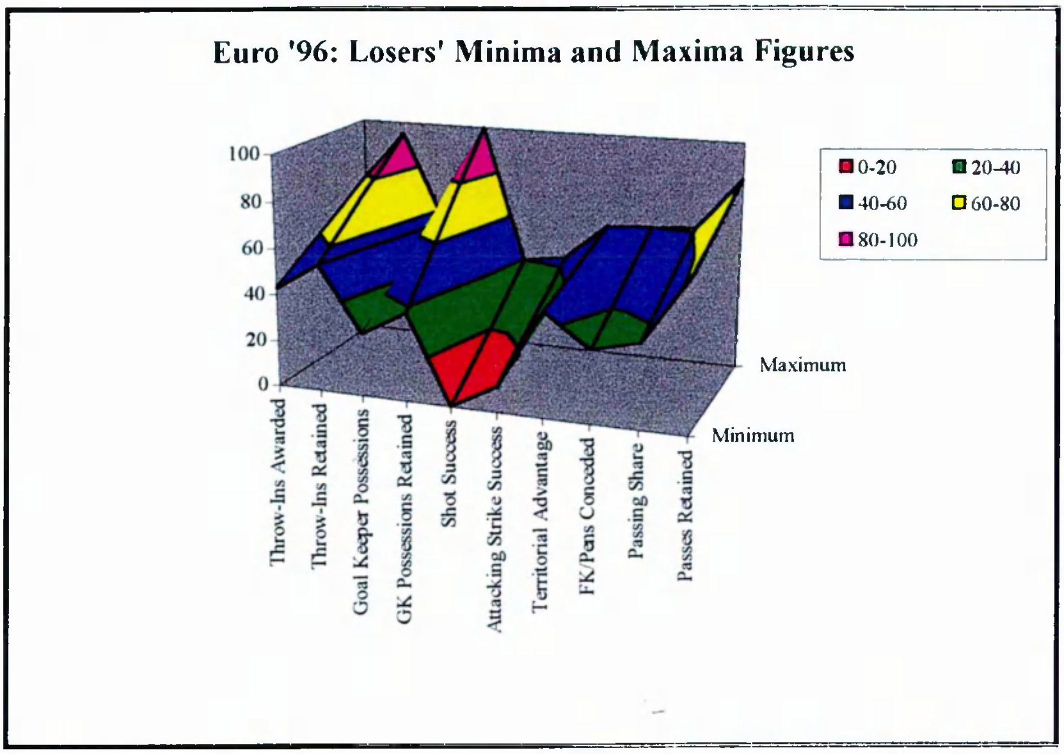

Figure 28: Losers' Minima and Maxima for Euro '96

In the 1994 World Cup the expected patterns of larger maxima and minima for the winners and lower ones for the losers does appear to a certain extent. Losers only have a higher minimum on one occasion and a higher maximum on one occasion. The range for throw-ins awarded is at a higher level for losers, but this is the only exception. The areas where winners have a distinct advantage are at the shooting success, corner share, and free-kicks and penalties awarded. They have an advantage, although only a slight one, in terms of passing share and goal-kicks awarded. Significantly, winners have maximum levels of 100% at corners' share and shooting success - both of these are attacking variables.

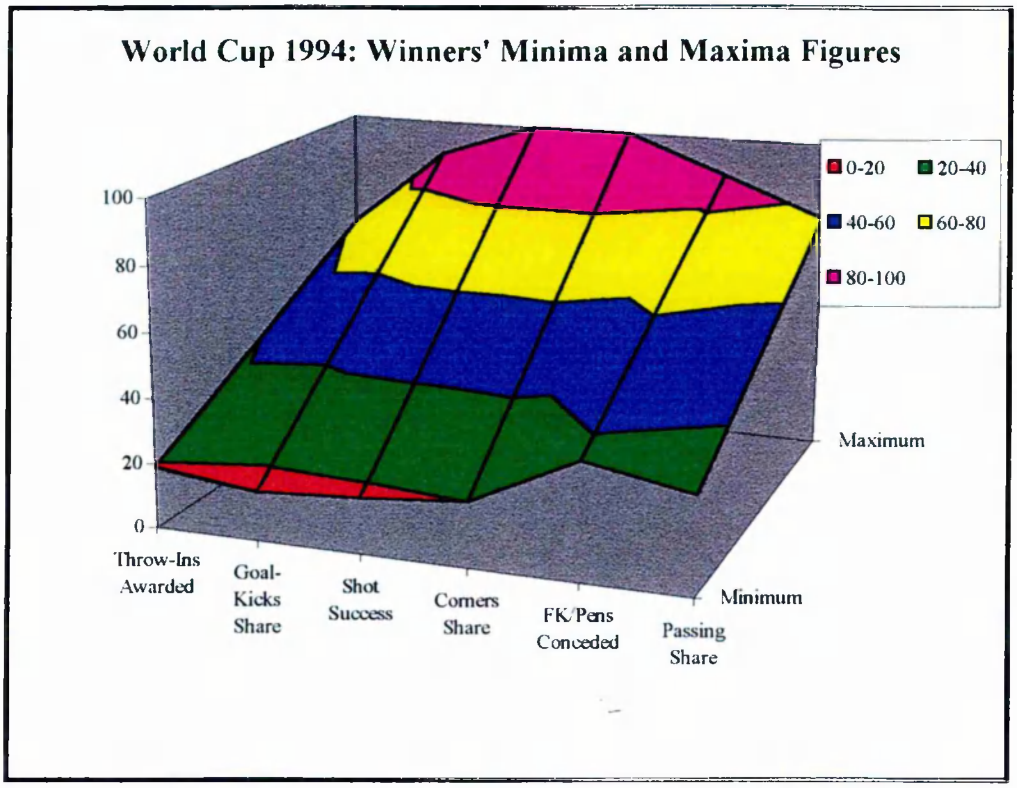

Figure 29: Winners' Minima and Maxima for USA '94

Although this type of investigation has some advantages there is an obvious limitation. The minimum and maximum figures used could all come from one match and therefore one particularly strong performance from a loser or a weak one from a winner would weigh heavily on the findings.

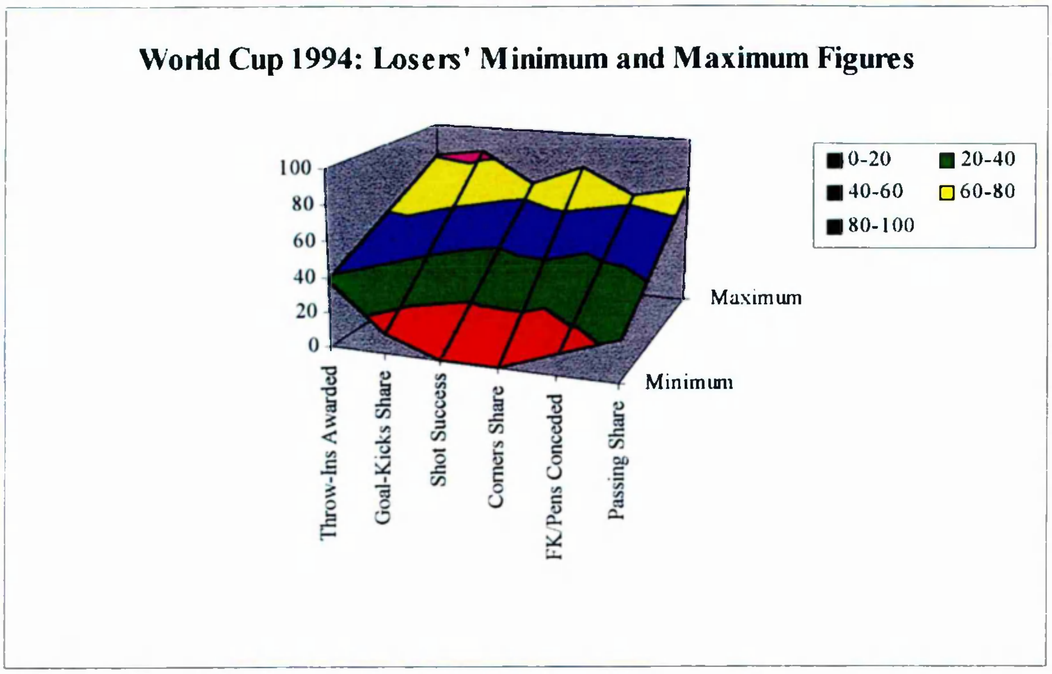

Figure 30: Losers' Minima and Maxima for USA '94

4.3.7 The Champions

When determining the pattern of winning performance in Euro'96, Germany achieved the following performance standards in ten key areas. The matches analysed were one group match and the three knock-out matches. Three of the matches were drawn, with Germany winning the two drawn knock-out matches outside normal playing time.

In their first match against Italy they had fewer throw-ins and goal-keeper possessions and a very low territorial figure. Against Croatia they again had fewer throw-ins and were more undisciplined. In the game against England they again did not have territorial dominance but had more throw-ins and free-kick situations, and against the Czech Republic they had fewer throw-ins, goal keeper possessions and free-kick situations and less territorial dominance. Germany did have effective success rates at attacking strikes. They were more than 38% successful in three of the matches. The other trend which is prominent is that their success rate at keeping possession improved as the tournament progressed (from 73.5% in the Italian match to over 83% in the final). Germany's mean performance in these areas over the four matches of the tournament illustrate what one would expect of a winning team's pattern. On average, they had fewer throw-ins and goal-keeper possessions, had attacking success rates within the 30 - 40% range, had a greater share of the passing but less territorial play and were marginally more undisciplined. Before one can conclude if Germany's performance in the 1996 European Championship tournament mirrors the expected performance of winners more data from other matches and competitions need to be analysed.

Table 30: Germany: Statistical Performance in Euro '96

Germany's Performance Indicators (%)				
Variable	**Mean**	**SD**	**Min**	**Max**
Throw-ins Awarded	44.72	11.19	35.00	60.87
Throw-ins Retained	79.39	13.62	64.29	90.91
Goal Keeper Possessions	47.75	6.53	41.46	56.52
GK Possessions Retained	69.00	21.60	42.30	94.10
Shot Success	33.68	12.75	22.22	50.00
Attacking Strike Success	35.39	6.98	25.00	40.00
Territorial Advantage	43.74	7.66	34.59	51.20
FK/Pens Conceded	50.78	4.03	45.45	54.55
Passing Share	51.33	7.83	44.20	62.30
Passes Retained	77.48	3.61	73.46	82.22

In the 1994 World Cup five matches were analysed (see Table 31). Brazil achieved the following performance standards in seven key areas. Two of the matches were drawn.

Table 31: Brazil: Statistical Performance in USA '94

Brazil's Performance Indicators (%)				
Variable	**Mean**	**SD**	**Min**	**Max**
Passing Share	65.90	3.42	56.31	76.09
Free-kicks conceded Share	50.00	1.31	47.06	54.05
Throw-in Share	50.00	4.27	36.96	58.82
Corner Share	73.20	10.90	33.33	100.00
Goal-kick Share	41.28	7.22	15.00	55.56
Total Shot Share	72.38	6.03	59.26	92.31
Shot Success	78.64	2.83	71.43	85.71

In their first match against Russia they had fewer throw-ins, but were more disciplined, and had more goal-kicks. Against Cameroon the pattern was the same - they again had fewer throw-ins, were better disciplined and had more goal-kicks. Against Sweden in the first encounter between the two teams, Brazil had more throw-ins, fewer goal-kicks and were more undisciplined. They drew this match. Against the same team in the semi-final they again had more throw-ins and less goal kicks but were better disciplined. In the final against Italy they conceded more free-kicks, had more throw-ins and less goal-kicks. They again drew this match. Brazil did have very effective success rates in the attacking variables. In every match they had better passing continuity than their opponents, and in four of the five matches they were awarded more corners than the opposition. The most noticeable aspect was the high share of shots on goal that Brazil had, always in excess of 50% and as high as 92% in one match. A further feature of this was their success at hitting the target with their shots. They had over a 70% success rate in every match. Brazil's mean performance in these areas over their five matches in the tournament which were analysed reflect what one would expect of a winning team's pattern. On average they had as many throw-ins and free-kicks as the opposition and fewer goal-kicks. They had attacking success rates in terms of shots within the 71 - 86% range, had a greater share of the passing, almost 66%, an average of over 73% of the corners, and between 59 and 93% of the total shots at a mean of in excess of 72%. Before one can conclude if Brazil's performance in the 1994 World Cup tournament mirrors the expected performance of winners more data from other matches and competitions need to be analysed but their dominance in terms of the attacking variables is particularly important.

4.3.8 Possession Count

Twenty matches in the 1996 European Championship were analysed using a computerised notation system. The figures discussed are the absolute figures that both the winning and losing team achieved. The number of possessions obtained from free-kick, goal-kick and throw-in situations are examined as well as the retention of this possession through the total number of passes (Table 32). The data are further examined by combining the free-kick, goal-kick and throw-in situations and grouping them as primary possessions. Overall the winners do not have more possession in any of the possession counts. As individual cases, the trend appears to be for winners winning more throw-in possessions in five of the matches, more goal-keeper possessions in seven matches, more free-kicks possessions in only two matches with another two equal, more primary possession in only in three of the matches and equal in one other, and more passing possessions in only four of the matches.

Table 32: Possession Count in Euro '96

	Throw-in possessions		Goal-keeper possessions		Free-kick possessions		Primary possessions		Passing possessions	
Match	**Win**	**Lose**	**Win**	**Lose**	**Win**	**Lose**	**Win**	**Lose**	**Win**	**Lose**
1	20	24	14	33	18	33	52	90	296	339
2	20	25	27	23	22	22	69	70	259	279
3	13	23	11	27	25	20	49	70	291	468
4	27	14	30	12	12	27	69	53	361	169
5	17	16	26	15	20	29	63	60	356	313
6	15	21	25	18	20	21	60	60	290	296
7	23	14	35	22	16	16	74	52	362	277
8	25	21	19	17	22	30	66	68	303	348
9	15	23	22	21	11	17	48	61	307	358
10	28	16	10	26	14	20	52	72	357	404
11	14	24	19	24	20	24	53	72	270	249
12	11	18	9	26	33	22	53	66	225	404
Total	228	239	247	264	233	281	708	794	3677	3904
%	48.8	51.2	48.3	51.7	45.3	54.7	47.1	52.9	48.5	51.5
Mean	19	19.9	20.6	22	19.4	23.4	59	66.2	306.4	325.3

In terms of the correlation between each variable and the winning margin none of the variables were significant at the 0.01 level. This is probably due to the small size of the data set, but at the 0.05 level the following variables did have a significant relationship with the winning margin:

1. Throw-in possessions winners - positive
2. Throw-in possessions losers - negative
3. Free-kick possessions winners - positive
4. Free kick possessions losers - negative
5. Passing possessions winners - positive

These significant relationships are the first evidence found that possession is an important indicator of winning performance. It is clear that throw-in possessions, free-kick possessions and number of completed passes do have a strong relationship with winning and losing.

Thirty three matches in the 1994 World Cup were also analysed and the data from the 23 conclusive matches were examined. Overall the winners only had more possession in terms of goal-kicks and passing possessions. As individual cases, the trend appears to be winners winning more throw-ins in seven of the twenty three matches, more goal-kicks in twelve matches, more free-kicks in seven matches, more primary possession in seven of the matches, and more passing possessions in thirteen of the matches.

In terms of the correlation between each variable and the winning margin none of the variables were significant at the 0.01 level. This is probably due to the small size of the data set, but at the 0.05 level the number of throw-ins awarded to losers had a negative correlation. The lack of many significant relationships is suggestive that the amount of possession is not an important indicator of winning performance.

However, by summing the amount of possession won and retained by teams one can discover whether it is an important indicator of winning performance. Although there were not many conclusive findings in the raw data the correlation with the winning margin was helpful and indicative.

Table 33: Possession Count in USA '94

	Throw-in possessions		Goal-kick possessions		Free-kick possessions		Primary possessions		Passing possessions	
Match	**Win**	**Lose**	**Win**	**Lose**	**Win**	**Lose**	**Win**	**Lose**	**Win**	**Lose**
1	20	15	4	14	20	16	44	45	396	282
2	17	20	8	6	18	25	43	51	232	549
3	18	23	9	8	13	14	40	45	446	346
4	25	15	6	12	16	17	47	44	510	158
5	19	23	5	15	21	19	45	57	449	347
6	17	25	7	9	19	12	43	46	304	320
7	19	23	12	6	10	19	41	48	243	559
8	24	21	5	5	18	32	47	58	393	276
9	22	37	11	12	18	16	51	65	362	281
10	17	29	10	8	19	20	46	57	449	274
11	24	26	8	12	18	19	50	57	368	365
12	12	10	16	13	16	28	44	51	348	403
13	15	9	9	13	5	37	29	59	478	283
14	14	19	14	9	21	16	49	44	342	342
15	22	23	9	5	29	17	60	45	330	394
16	18	18	17	12	23	13	58	43	361	368
17	19	24	15	6	24	22	58	52	270	297
18	14	19	13	10	10	10	37	39	416	324
19	6	25	16	2	22	22	44	49	241	428
20	19	19	14	11	16	19	49	49	384	325
21	28	19	4	9	18	14	50	42	423	215
22	19	28	11	6	30	18	60	52	327	419
23	17	16	3	17	16	18	36	51	602	252
Total	425	486	226	220	409	443	1071	1149	8674	7807
%	46.7	53.3	50.7	49.3	48.0	52.0	48.2	51.8	52.6	47.4
Mean	18.5	21.1	9.8	9.6	17.8	19.3	46.6	50.0	377.1	339.4

4.3.9 The Yes/No Challenge

In Euro' 96, twenty-one performance categories or sub-categories were used to record and compare data for winners and losers. The number of times the winning side had greater success than the losers was recorded for each variable. Ten matches were recorded. In all cases the winners consistently performed better than the losers in attack and defence efficiency. However, this is not as significant as in the rugby model since there is only one way of scoring in soccer. One would expect that the attack and defence efficiencies to be better because of the ratio of goals scored to the total number of attacks. However it is possible for the losers to perform better than winners in some categories. In nine of the matches the winners had more passes intercepted. This one would not expect. In eight of the matches losers also had greater territorial dominance.

The next step was to discover whether winners had overall dominance in the majority of the variables in any match. This was found not to be the case since it was only in 4 of the 12 matches that the winning side had greater success in 15 or more of the 21 variables. A frequency table of the number of times that the winners had greater success than the losers is shown below. The ten matches were again analysed. In the Croatia v Denmark match which Croatia won by 3 goals to nil, Croatia performed better than Denmark in 16 of the 21 variables.

In order to further investigate key performance indicators in association football, variables were put into four categories: territorial pressure (territorial dominance and times in opposition penalty area); set-piece possession (throw-ins awarded, goal-keeper opportunities and free-kicks and penalties awarded), effective attacking game (success in all aspects of attacking game), and continuity and ball retention (time in control, passes attempted, passes retained and lost). With the variables within these four categories the exercise was now be repeated. With the variables now grouped together in these identifiable areas it is more clear to see which areas are more important than others. Pressure through territorial dominance and entries into the opposing penalty area were important in half of the matches as was attacking strikes at goal, and in four of the matches ball retention was important for the winners. Set-piece possession dominance was not achieved by any of the winning sides. These areas do not appear to be necessary conditions for winning performance. The nature of the game of soccer is different from rugby union. Since goals are rarer and are the only means of scoring then it allows the possibility for teams to win through one strike at goal. Four of the winning sides did not achieve dominance over the losing side in and of the four areas in 4 of the 12 matches. They were better in only one area on one occasion, better in two areas on 6 occasions, 3 areas only once and never better in all four areas. There was also no evidence of a particular side showing constant patterns when they won. Only France in two matches showed a tendency to play a pressure game with many strikes at goal.

In the Soccer World Cup 1994, 13 performance categories or sub-categories the respective figures for both the winners and losers was recorded for each match and compared. The number of times the winning side had greater success than the losers was recorded for each variable. Twenty three matches were recorded. The aspects in which winners had better results than the losers most consistently were the number of shots on target and the passing continuity of the teams between 8 and 11 and over 12 passes.

The next step was to discover whether winners had overall dominance in the majority of the variables in any match. This was the case only to a certain extent since it was only in 8 of the 23 matches that the winning side had greater success in 9 or more of the 13 variables. Twenty three matches were analysed. In the Argentina v Nigeria match which Argentina won by two goals to one, Argentina performed better than Nigeria in 12 of the 13 variables. Also, Brazil achieved dominance in 11 of the 13 variables in their three to nil win against Cameroon. In Romania's 3 - 2 win against Argentina though, the Romanians only enjoyed greater gross figures in two of the thirteen areas.

In order to further investigate key performance indicators, the variables were then consolidated into three categories: set-piece possession (throw-ins awarded, goal-kicks and free-kicks and penalties awarded); effective attacking game (total shots and shots on target); and continuity and ball retention (passes retained and cycles of passes in excess of seven passes). Strikes at goal was important for the winners in 11 of the matches. Set-piece possession dominance was only achieved by a third of the winning sides. Ball retention was the most important area with the winners enjoying dominance in this area in 15 of the 23 matches. Six of the winning sides did not achieve dominance over the losing side in any of the three areas in their matches. They were better in only one area on six occasions, better in two areas on six occasions, and better in all three areas six times. There was evidence of a particular side showing constant patterns when they won. Brazil, the eventual winners had dominance in all three areas in four of the matches which they won, and in two areas in the other match. They dominated both continuity and strikes at goal in every match and set-pieces in three of the four. Germany also had better continuity in both the matches analysed in which they won.

On this evidence it would appear that winning performance in association football is much more complex than the comparison of gross performance indicators of winning and losing sides, particularly in one-off matches. However, Brazil's performance in the World Cup does suggest that winning performance in a tournament can generate indicators amenable to further analysis.

This Yes/No investigation identified whether in any particular match where there was a conclusive result, the winners performed consistently better than the losers in a particular variable. By clustering the variables the results could be examined in terms of different aspects of the game. However, the size of the data sets were again limiting particularly in the soccer tournaments where decisive matches are not as common as in rugby.

4.3.10 Spearman's Rank Correlation Coefficient

The performance of the winning and losing side in each of the Euro '96 matches in respect of a number of variables was notated and analysed. The relationships between these variables and the winning margin were tested for significance by calculating a Spearman's Rank Correlation Coefficient. A limiting factor was the size of the data set, only twelve matches were notated. The data collected were grouped in five categories: territory and goal-scoring; primary possession; discipline; attacking strikes; and ball retention.

For n=12 the significant levels for correlation are 0.506 at the 0.05 level and 0.712 at the 0.01 level. The data for territory and goal-scoring are significant at the 0.05 level in three of the variables: times in own penalty area; goals scored; and attack efficiency. At the 0.01 level it is only the goals scored that has a significant relationship with the winning margin. At the 0.05 level six of the throw-in variables had a significant relationship with the winning margin. The number of throw-ins awarded (absolute and relative), the throw-ins where possession was retained, and the total number of throw-in possessions won (absolute and relative) had a positive relationship, while the number of throw-ins that the opposition won had a negative relationship. At the 0.01 level it was only the percentage of throw-ins awarded that was positively significant.

In terms of the goal-kick variables none were significant at any of the levels. The ability to retain the ball was measured and although there was no significant relationship at the 0.01 level, at the 0.05 level the absolute number of passes attempted, and the number of passes retained (both absolute and relative) were significant. In terms of discipline the number of free-kicks and penalties both conceded and awarded were significant with the winning margin but in a negative relationship while those conceded within the opposition's half were also negatively significant. The only attacking strike variable that showed a significant relationship with the winning margin was the percentage of shots, crosses, corners that were on target. This variable was significant at both the 0.05 and the 0.01 level.

The performance of the winning and losing side in each of the USA '94 matches in respect of a number of variables was notated and analysed. The relationship between these variables and the winning margin were tested for significance by calculating a Spearman's Rank Correlation Coefficient. The size of the data set was twenty three matches. The data collected were grouped in four categories: shooting and goal-scoring; primary possession; discipline; and ball retention. For n=23 the significant levels for correlation are 0.351 at the 0.05 level and 0.496 at the 0.01 level. The data for goals scored in the second half are significant at both the 0.05 and at the 0.01 level.

None of the correlation coefficients for the shooting being on target or not were significant at the 0.05 and at the 0.01 level. The only variable within primary possession which was significant was a positive relationship between opposition throw-ins and the winning margin. In terms of the goal-kick variables only one was significant at any of the levels and that was the number of times the goal-keeper played the ball short from his possessions. This variable had a negative relationship with the winning margin.

The ability to retain possession of the ball was measured and although there was no significant relationship at the 0.01 level, at the 0.05 level the absolute number of passes attempted, and the number of passes retained (both absolute and relative) were significant. In terms of discipline there was no significant correlation.

This method is preferable to the Pearson's Product Moment Correlation because Spearman's Rank Correlation is a non-parametric test. It identifies key variables and this proved illuminating particularly in respect of the rugby union data.

4.3.11 Performance Profile

Each country's performance in each of the variables was measured for every match analysed in Euro '96. This provided sufficient data to provide average figures for each country that could be correlated with their final position in the tournament. Their final position was calculated by:

1. Germany, the winners were placed first.
2. Czech Republic, the runners-up were placed second.
3. England and France, losers in the semi-finals, were placed equal third.
4. Croatia, Portugal, Holland and Spain, all losing quarter-finalists, were placed equal fourth.
5. Denmark, Bulgaria, Romania, Turkey, Italy, Switzerland, Scotland, and Russia, all qualifying group losers, were placed equal fifth.

At the 0.05 confidence level the variables which had a significant correlation with the team's final placing in Euro '96 were:

Positive correlation:	Winning Margin	Goals scored
	Attack Efficiency	Defence Efficiency
	Shooting success	
Negative correlation:	Goals conceded	Free-kicks/Penalties awarded

At the 0.01 confidence level the variables which had a significant correlation with the team's final placing in Euro '96 were:

Positive correlation:	Winning Margin	
Negative correlation:	Goals conceded	Free-kicks/Penalties Awarded

4.3.12 The Game Rhythm

The association football game rhythm charts followed much the same structure as the rugby union charts with certain modifications. The scoring sequence was obviously now restricted to the one method of scoring and the soccer performance indicators replaced the rugby union ones! The only other change was the need to scale the cumulative axes so that the passing continuity could be recorded. The game rhythm charts from Euro '96 are shown in Appendix D. The Croatia v Denmark match (16 June 1996) is discussed here and is illustrated in Figure 30.

In terms of the activity cycles, the soccer charts demonstrate much longer cycles than rugby union with one team or the other in possession for longer periods as well, while the territorial signature is more intermittent suggesting that territory is not as important a factor. The most striking feature of the graphical output is the cumulative passes. The first half signature shows a slight advantage to the blue of Croatia, with regular passages of passing reaching six or more passes. There are no goals scored in the first half but this retention of possession formed a solid platform for the second period. During this half the Croatian's dominance of possession is considerable. They have cycles of six passes or more and reach up to twenty-four continuous completed passes during the third quarter.

The advantage of the game rhythm charts being able to link the events is evident in the way that the passing signature can indicate the build up to goals scored. The Croatian's first goal only had one pass leading up to it, the third did not have any, but the second goal had a period of possession leading to it. There was a cycle of twelve passes before possession was regained and a goal scored. This period of possession also involved two crosses. The first was not successful and probably signalled the end of the twelve pass cycle before the second successful cross led to the goal. The crosses also correspond with attacks into the opposition penalty area and Croatia have more in the second half which ties in with their greater possession.

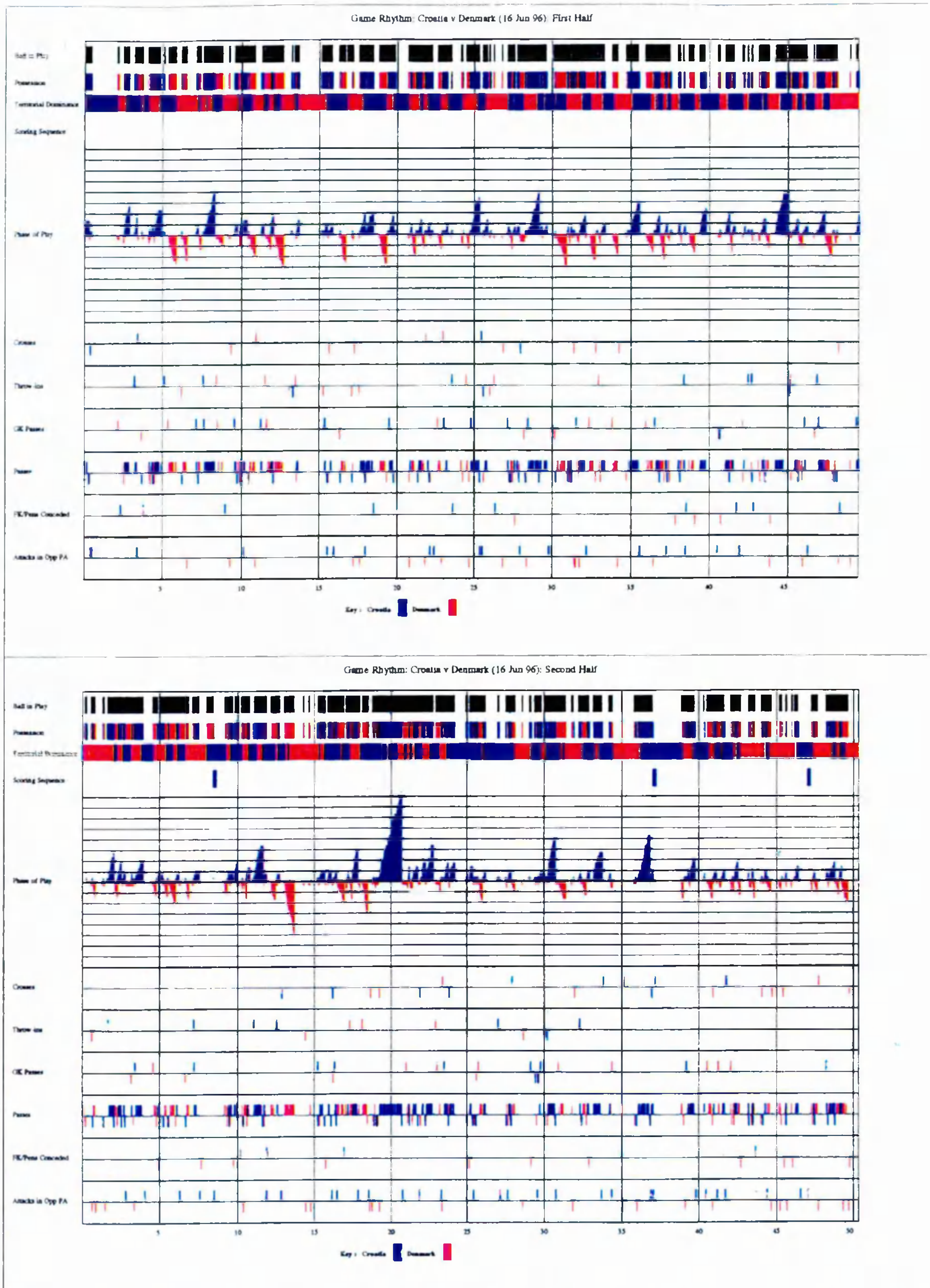

Figure 31: Game Rhythm Chart: Croatia v Denmark (16 June 1996)

4.3.13 Time Intervals

The performance of winners and losers was viewed with attention to the average frequency of the variable and the time interval during which they occurred. The data were examined by looking at the winning teams as individual cases and as a collective category. As with the corresponding investigation into the rugby data a chi-square test was carried out for each variable to determine whether there was a significant difference in the proportions of winners and losers within each time interval. If the calculated value exceeded the critical value in the table, then the null hypothesis was rejected.

There were distinctive patterns in the data for the goal scoring time intervals. Firstly, in the matches analysed the winners scored twenty five goals whilst only conceding four. The losers did outscore the winners in the 71-80th minute interval and there were no goals scored in the second and fifth time interval but the other seven intervals showed the winners to be dominant. The winners' dominance was very strong in the second-half.. They outscored the losers in four of the five intervals here by 6-1, 5-0, 4-0, and 2-0. Since the data set of goals scored was not very large there was little to conclude from the timings of the goals scored by the individual countries. The one obvious pattern that did exist was the lack of goals in the data of the countries that failed to progress from the knock-out stages!

In only three of the first six ten minute intervals do winners have more entries into the opposition penalty area than losers, and in the final four periods not once does this happen. Overall the number of entries was 457 by the winners and 492 by the losers.

When the figures are examined for each individual country then there again seems to be little evident pattern. The majority of the teams that progressed to the latter stages of the tournament, for example, Germany, England, France, Croatia and Portugal have consistently high number of entries into the opposing penalty area during each of the ten minute intervals. They regularly have over twenty entries per period and always over ten. However, this cannot be deemed an indicator of winning soccer since the Czech Republic, who reached the final, only record a double figure of entries on two occasions and are as low as three on two occasions. This suggests that it is not the number of attacking plays in the opposing penalty area which is important but the quality of the final attacking strike.

Another variable that winners might be expected to differ from losers is the number of shots on target (shooting success). Some researchers (see, for example, Hughes, 1990) have stated that they have no evidence of teams losing if they have had ten or more successful shots in a game. The average figures for successful shots in this study indicates that winners had more shots on target than losers in eight of the ten time intervals. Overall the count was one of 56 - 29. Once again there seemed to be a pattern of winning teams executing far more successful shots than the losers in the second half of a match (28 - 8). The eight teams who qualified from their groups had an average number of successful shots ranging from 7 to 17, while the range of the losers was 1 to 8.

Throw-ins awarded and retained would not appear to be key performance indicators other than that they provide a team with a chance of possession. When the results are examined in terms of the averages of winners and losers in a particular match, then the losers consistently (9 out of 10 occasions) have more throw-ins than the winners. However the data for each individual country show the winning teams to be regularly recording double figure amounts of throw-ins awarded and possessions retained whilst losers do not once record such a figure.

The goal-keeper possessions and the retention of this possession indicate strong differences between winners and losers once again. On average, the winners in any one match do not once have fewer number of goal-keeper possessions than the losers. This pattern is not as strong in the retention of the possessions but only due to the losers keeping the ball more from goal-kicks in the final three ten minute intervals.

The other investigations discussed in **4.3** have indicated that over the course of a whole game the global figure of passes is an important indicator of winning performance. Brazil are a testament to this relationship. The time interval investigation enabled closer inspection of passing movements. As far as winners in any particular match was concerned there was little evidence of passing being a key variable in any of the ten time intervals of the matches in Euro '96. The average figures showed that only twice did winners attempt more passes than losers and only three times did they complete more passes. Their retention success (passes attempted over passes completed) further emphasises a lack of any correlation between passing continuity and winning as both winners and losers display a success rate with their passing of 79%. The rate at each of the intervals is always in close proximity to this average figure.

However, the passing routines of each individual country definitely indicate a difference. The eight teams who qualified for the later stages consistently made in excess of one hundred attempted passes in each ten minute period. If the 91^{st} -100^{th} minute period is excluded (because it is not a complete period) then the eight teams attempt 100 passes in 62 of the 72 intervals while the corresponding figure for the teams who failed to qualify is only 8 out of 72. The maximum a losing side attempts in any ten minute interval is 138 but winning sides regularly attempt over 200 - Germany (203, 205, 204) and Portugal (253, 226, 234, 200, 224). The pattern in completed passes further emphasises this point.

A chi-square test was carried out on all the variables with the exception of goals scored and successful shots because these had many cells with values below five. In all the other variables, at the appropriate degrees of freedom level, the calculated value exceeded the critical value in the table, which meant that each null hypothesis could be rejected. This therefore illustrated that there was a significant difference in the patterns of the winners' and losers' data in the ten minute intervals of the matches.

4.4 Conclusion

This chapter has presented and discussed the results of fifteen investigations into winning and losing performance in rugby union football and thirteen investigations into winning and losing performance in association football. These investigations were undertaken in order to respond to the four research questions set.

The material presented and discussed in this chapter has directly addressed research questions 1 and 2 . Data have been collected in real-time with hand and computer notation systems. Considerable time has been devoted to identification of patterns of winning and losing behaviour in rugby union and association football. In the next chapter, research questions 3 and 4 will be the focus of discussion but will build upon the foundations laid here.

What is evident from the investigations presented in Chapter Four is that even in two invasive team games there is considerable complexity in the patterning of winning and losing performance. A rich picture of winning (and losing) has to incorporate a range of quantitative and qualitative data. Such data relates to macro-structures of game playing as well as to micro-situations of player performance and action.

The first aim of the study was to identify patterns of winning performance in two invasive team games. Chapter Four is presented as a substantive response to this aim. In the next chapter, the second aim of proposing a generic model of winning performance in these games is addressed.

Chapter Five: A Model For Winning Performance

5.1 Overview

Aim Two of this study was to propose a generic model of winning performance in the invasive team games of rugby union football and association football. In order to achieve this aim the research used empirical investigation to generate a database of performance in these games. The essence of this research was to provide a macro-structural account of winning whilst at the same time enriching that model with micro-situational actions.

As with More's (1994) analysis of coaching behaviour, the intention was to develop a data driven model of winning performance. Although there is a range of models available to conceptualise performance the research was not conceived to test an *a priori* model or models. Rather the research enterprise was committed to the identification of patterns of winning performance in two invasive team games (Aim 1) as a necessary condition for proposing a generic model of winning performance (Aim 2). It was decided that such an approach would make it possible to use emergent data to model performance. Indeed it became evident that not only was winning performance complex but also that the models discussed in Chapter Two had elements that could enrich discussion of performance without being prescriptive. This dynamic relationship between data and concepts enabled a much more creative approach to modelling winning performance. Thus the research dared to consider a theory building rather than a theory testing approach.

Models can be used as a form of creative thought which can initiate new ideas. In this sense, modelling is as much an ongoing process as it is a finished product. In this chapter the potential of an 'ideal type' model enriched by empirical data is considered.

5.2 The Ideal Type

A model is an abstract representation that assists us in seeing something more clearly. Max Weber (1947), a German sociologist, recognised the heuristic potential of models. He was particularly interested in the concept of the 'ideal type' as an abstract model. When used as a standard of comparison, the ideal type enables an understanding of the 'real' world.

For Weber, the ideal type is a model that over-simplifies reality so that its most important characteristics can be identified. He also suggested that an additional requirement is that this model must be "objectively possible" and "subjectively adequate". In this sense as well as being able to approximate the model with reality, it must be able to equate with the requirements of those involved with that reality. Throughout this study the focus group provided support in achieving this subjective adequacy.

In Weber's (1947) thinking the 'ideal type' aids the clearer description and analysis of historical cases and involves the understanding of specific cases. Weber himself exemplified this commitment to meticulous empirical scholarship as the foundation of theorising. This approach facilitates the construction of an ideal type model for comparative studies and the opportunity to explore whether there are any generic possibilities. Weber (1947) was at pains to emphasise that the ideal type was open to development and replacement. Its richness for this study comes from its potential to be revised. As such it is a fallible intellectual approach to the real world that reflects behaviour in that world.

Ideal type models identify key characteristics in a pure, abstract, exaggerated sense that is unlikely to exist other than as a mental construct. However, the lack of fit between the ideal type and the real world does not constitute a problem since the purpose is not to describe and explain the subject but rather to provide a point of comparison from which to observe it.

5.2.1 A Winning Rugby Ideal Type

Two rugby union data sets were used to formulate a winning rugby ideal type. These data were presented and discussed in Chapter Four. They comprise the Five Nations' Championship (an annual tournament) and the Rugby World Cup (a quadrennial tournament).

Care was taken to model winning performance for a single case (one game) and for a tournament (all games). Ideal type models were formulated for each data set.

An Ideal Type of Winning Performance in a Rugby Union International Game (Five Nations' Championship)

EXTRANEOUS INFLUENCES

The team plays at home, with a referee who has not officiated the team recently.

KEY PERFORMANCE AREAS

The team achieves territorial dominance and maximises the number of attacking opportunities within the opponent's 22 metre area. The team maintains possession of the ball when primary possession is secured.

SCORING

The team scores the first try and has a half-time lead.

Figure 32: An Ideal Type of Winning Performance in a Rugby Union International Game (Five Nations' Championship)

An Ideal Type of Winning Performance in a Rugby Union Tournament (Five Nations' Championship)

EXTRANEOUS INFLUENCES

The team is officiated by different referee on each occasion.

KEY PERFORMANCE AREAS

The team achieves territorial dominance and a greater proportion of the set-piece situations particularly the line-out.
It establishes platforms for second phase continuity.

SCORING

The team scores more tries than the opposition.

Figure 33: An Ideal Type of Winning Performance in a Rugby Union Tournament (Five Nations' Championship)

An Ideal Type of Winning Performance in a Rugby Union World Cup Tournament

EXTRANEOUS INFLUENCES

The team hosts the tournament or has as settled a base as possible.
The team is officiated by referees who are not accustomed with its pattern of play (Southern Hemisphere referees for Northern Hemisphere teams and vice versa).

KEY PERFORMANCE AREAS

The team achieves territorial dominance, a greater proportion of set-piece situations (line-outs, scrums, penalties) and second phase platforms.
The team is able to stop the opposition from scoring tries.
The team has a successful all-round kicking game.

SCORING

The team scores the first try and holds a half-time lead.
The team scores more tries than the opposition and has a high goal-kicking success rate.

Figure 34: An Ideal Type of Winning Performance in a Rugby Union World Cup Tournament

5.2.2 A Winning Association Football Ideal Type

Two association football data sets were used to formulate a winning ideal type. These data were presented and discussed in Chapter Four. They comprise two quadrennial tournaments: the European Championship (Euro '96) and the World Cup (USA '94).

An Ideal Type of Winning Performance in
an European Association Football Tournament

EXTRANEOUS INFLUENCES

The team has the advantage of home ground.

KEY PERFORMANCE AREAS

The team has the majority of throw-ins and free-kick possessions.
The team maintains continuity of the ball and is effective in all attacking strikes (shots, headers, corners, crosses.).

SCORING

The team scores first and holds a half-time lead.

Figure 35: An Ideal Type of Winning Performance in an European Association Football Tournament

An Ideal Type of Winning Performance in
a World Cup Association Football Tournament

EXTRANEOUS INFLUENCES

The team hosts the tournament or has as settled a base as possible.
The team is officiated by referees who are not accustomed with its pattern of play.

KEY PERFORMANCE AREAS

The team concentrates on keeping possession of the ball for long cycles of play.
The team has the greater number of corners and shooting opportunities.
The team has as many shots on target as possible.

SCORING

The team scores the first goal and holds a half-time lead.
The team is able to score in the second half of a game.

Figure 36: An Ideal Type of Winning Performance in a World Cup Association Football Tournament

Care was taken to model winning performance for the tournaments as a whole (all games). As indicated in Chapter Four, the association football data showed substantial within-game difference that made it difficult to abstract a meaningful ideal type model for one game.

5.3 A Generic Ideal Type of Winning Performance for Invasive Team Games?

The modelling of winning performance is fraught with conceptual and empirical difficulties. In Chapter Two the credentials of a number of extant models were discussed. What is evident after a four-year investigation into winning performance is that within-game, between-game and between sport differences limit the scope of generic models.

However, it is suggested that an approach that makes use of the Weberian ideal type is profitable and generative. To this end the ideal types were presented in **5.2**. There appear to be patterns of winning (and losing) performance related to extraneous influences, key performance areas and scoring patterns. Remarkably after four years' search for invariant structures in two invasive team games the real work is beginning! The limits and ranges of any ideal type are set in part by the variance in performance. Like other theoretical enterprises it is important here to acknowledge the dynamic interplay between structural modelling and the phenomenology of moments.

With these caveats entered, it is proposed to offer an ideal type of winning performance for two invasive team games. In true Weberian spirit, this ideal type can be tested not only against these games but also against other invasive team games.

An Ideal Type of Winning Performance in an Invasive Team Game

EXTRANEOUS INFLUENCES

The team optimises opportunities provided by home-ground advantage.
The team is officiated by referees who are not accustomed with its pattern of play.

KEY PERFORMANCE AREAS

The team is focused on gaining primary possession.
The team retains possession.
The team sustains territorial dominance and translates this into scoring opportunities.
The team has effective strike plays.
The team has effective defensive strategies.

SCORING

The team scores first and holds a half-time lead.

Figure 37: An Ideal Type of Winning Performance in an Invasive Team Game

This limited ideal type of winning performance in an invasive game reflects the difficulties associated with generic performance issues. However, other things being equal, this ideal type does identify the causality of winning. What is particularly interesting is that whilst winners are able to mobilise these structures consistently, exceptional teams are able to overcome some of these structures to transform a losing profile into a winning one. That these teams do provide an exception to the ideal type suggests the adequacy of the ideal type! These exceptions can be investigated to further refine the ideal type.

The generic ideal type is based upon observable and measurable behaviour. Throughout the study it has been evident that there are some aspects of performance that cannot be measured. It is extremely difficult, for example, to present qualitative data in relation to individual virtuosity. As with other scientific endeavours, trying to find a 'theory of everything' poses formidable challenges. The next stage in this quest for a model of winning performance is to develop procedures and research instruments that are sensitive to individual action as well as macro-game structures.

5.4 Conclusion

In **2.4** the literature relating to a number of performance models was presented. In Chapter Four, thirty investigations into winning (and losing) performance were discussed. In this chapter, an attempt has been made to synthesise this material into an ideal type of winning performance.

It is evident from this four-year investigation that opportunities to model performance are increasing. The availability of high specification microcomputers has transformed the ways in which data are processed.

It is suggested that any attempt to model winning performance in invasive games will be enriched by recognising that a model can incorporate quantitative and qualitative data. These data can drive the modelling process. The ideal type has been presented here as a sensitive, heuristic model open to modification. In Weberian spirit this approach is focused on the dynamic interplay between structure and action.

As sports scientists try to develop a gender neutral language of performance for the twenty-first century it is important to attempt to develop an understanding of performance as a generic activity. This study has attempted to address these issues by using the empirical specification of two invasive games to develop a model of winning performance.

The final chapter of the thesis will summarise the study and identify future directions for research.

Chapter 6: Conclusion

6.1 Re-View: Aims and Research Questions

This investigation was intended to make a unique contribute to the academic study of performance in sport. Although the aspirational culture of notational analysis has had a commitment to the modelling and prediction of performance, to date much of the actual work has been descriptive. A small cluster of researchers in a variety of academic environments have attempted to model performance. Their work has been noted in this thesis and has been used as a catalyst for the study reported here. Thus whilst it is proposed that the present study makes a distinctive contribution to the literature, it is also argued that it is part of a cumulative tradition of research and enquiry.

Two aims were identified at the outset of the study. The first aim was to identify patterns of winning performance in two invasive team games. The second aim was to propose a generic model of winning performance within these games. Four research questions were formulated from these aims to focus conceptual and empirical investigations.

These research questions enabled the researcher to focus on first order ('factual') and second order ('conceptual') issues in a developmental manner. For the reasons identified in Chapter One, the study focused on winning performance and was delimited to two invasive team games. The research questions moved the research process from data collection to modelling and prediction.

It is proposed here that the study achieved its aims by responding in detail to the research questions. Patterns of winning performance were identified in two invasive team games. A generic model of winning performance within these games has been proposed. However the limited range of the model is acknowledged. The research reported here is viewed by the researcher as part of a journey that will continue after formal study is concluded. Two governing bodies of sport included in the focus group are determined to further develop the work. Winning performance has enormous personal and cultural significance for these governing bodies!

6.2 Winning

'Winning' and 'performance' are keywords in the research. Invasive team games have an absolute definition of winning enshrined in their rules and laws. The strategy in this study was to use empirical data of winning teams to develop a model of winning performance. Data were collected by systematic observation using valid and reliable real-time notation systems. At no point did the researcher interview coaches and performers about the games played. Thus there was no possibility of identifying any relative outcome goals a team may have had.

The data collected from 105 international standard games provided the foundation for the generation of a model of winning performance. The difficulties inherent in this process were identified in Chapters Four and Five. Despite the range of performance characteristics exhibited by winners in two different invasive team games an attempt was made to present a number of ideal type models of performance. These are presented in Figures 31 to 36 in Chapter Five.

The robustness of these ideal types is open to empirical investigation. It was suggested that some teams manage to overcome the model in so far as that to all intents and purposes they should have lost! It was proposed that these teams are not the exceptions that break the model. Perversely, in winning against the odds they offer a challenge to make the model more robust. Many models use pre-emptive phrases such as 'under normal conditions' or 'other things being equal' to try to deal with the disorderliness and asymmetry of the real world. To further develop this research even more effort will have to be invested in gathering fine-grain qualitative data that enrich the understanding of the links between individual actions and macro-structural winning performance. Such data should also stimulate debate about the necessary and sufficient conditions of winning.

6.3 Methods

The researcher set out to establish valid and reliable real-time notation systems that could be used to collect data for performance indicators that the focus group had identified as being an integral part of winning performance in invasive team games. The data collected could then be used to investigate whether winning teams had observable patterns of behaviour. Data were collected in real-time (in-event) with hand and computer notation systems during international rugby union and association football fixtures. Real-time data were collected since it was believed that the development of a model based on data collected in this way would bring the work of coaches and analysts closer together. The use of the hand notation systems was considered to be an essential part of the whole research process. They were based upon a tried system which had been tested rigorously for validity and reliability. The computer notation systems were developed as extensions to the hand notation systems.

Considerable attention was paid to the validity and reliability of the research instruments. Evidence of this commitment can be found in Chapter Three and Appendix B. The systems were used by the researcher. No data are presented here from other observers other than the reliability studies. No secondary data sets were used and thus all data were collected under protocols established by the researcher. Throughout the thesis emphasis has been placed on the transparency of the methods used so that the work can be replicated. The difficulties one colleague had in undertaking an inter-observer reliability study in real-time attests to the care that must be taken to learn the systems. By the end of the research process, the researcher had eight years' experience in using such systems.

At the end of the data collection process a range of computer technology had become available. The rapid processing power of microcomputers will become an integral part of future modelling processes. To this end there will need to be active consideration of the role hand notation plays in fundamental research. Developments in relational database architecture and application combined with the opportunities to use parallel processing will mean that iterations within large databases will be more and more possible.

However, as coaches in the focus group indicated, there will always be a place for pen and paper notation in applied research. It is the mix of these technologies that provides the challenge for future research in notational analysis.

6.4 Data

Chapter Four presented and discussed the data collected by the hand and computer systems. A number of investigations of the data were undertaken in an attempt to develop a model of winning performance in invasive games. The investigations were wide and varied. A database of the game content was discussed so that all further investigations would have a reference point. The effect of extraneous influences on the end result were examined and windows of opportunity were proposed for winning performance. Basic comparisons were made between winners and losers in any one particular match as well as more in-depth statistical tests on the importance of key performance indicators on the result of that match and on the longer term success of a team. An important step in the analysis was the introduction of time-based data and the division of the games into ten minute intervals. The game rhythm charts enabled the sequence of events to be followed and related to each other, and the intervals allowed for closer inspection of patterns of play of both winning and losing teams at different stages of the match and overcame the limitations that existed when using the whole match statistics.

Two statistical procedures were reported in Chapter Three and their uses are indicated in Chapter Four. These procedures (Spearman's Rank Correlation Coefficient and the Chi-square test) were used to explore statistically significant relationships between performance variables and winning outcome. The use of these methods was an important part of the researcher's learning experience. Prior to the research, the researcher had little background in statistical procedures.

A third statistical procedure was used to treat the data. Pearson's Product Moment Correlation was used to discover whether there were differences in the patterns of play of winning and losing teams. This initial test was not reported in the research as it failed to identify any important trends and was better suited to normally distributed data.

All data collected in the study are available for secondary statistical analysis. The production of research papers linked to this thesis will actively consider how statistical procedures can be used to share the data with sports science colleagues. This particular aspect of the research poses the researcher with the most important on-going professional development challenge.

The applicability of each investigation varied within a sport and between sports. They did highlight, however, the importance of certain variables in both of the two invasive team games chosen. Territorial dominance, attacking opportunities, ball retention and elements of scoring were deemed as very important to the end outcome of a match and the longer term success of a team. These findings made it possible to contemplate the modelling of winning performance.

6.5 Modelling

Throughout this thesis there has been a discussion of macro-game structures and micro-game situations. It was suggested in Chapter Five that an ideal type model was a helpful way of conceptualising winning performance and linking these macro and micro aspects. The limitations of this modelling process are evident in the generic ideal type model for winning performance in invasive games.

The diversity within and between sports has indicated that the aspiration to have 'a theory of everything' must be enriched by detailed qualitative data. In this respect models of behaviour such as catastrophe, chaos and critical incidents offer insights. Over a four year period the research has gathered data sets that give an understanding of invariant structures of winning performance but, as was suggested in Chapter Five, the variance of performance offers a window of opportunity to develop a more robust generic model. Obviously this modelling imperative is a long term commitment that will extend beyond the confines of this thesis.

However, it is suggested that the distinctiveness of this thesis and its contribution to the body of knowledge in sports science is the attempt made here to address modelling issues. As was indicated in Chapter One, this quest for models is linked to the epistemology of notational analysis from its 1980s genesis.

Weber (1947) had suggested a method of modelling called 'ideal type', with which one could relate to the real world whilst at the same time simplifying the complex structures involved. This approach was used to create a generic model of winning performance. It was noted in Chapter Five that this Weberian approach to modelling had considerable potential. In particular the openness of the ideal type to empirical challenge and change was particularly attractive.

This study was predicated on the desire to develop a data-driven model of performance. It was thus more an enterprise in theory-building rather than theory-testing. Other models considered included catastrophe, chaos and critical incidents. All of these can enrich the modelling process. All three attempt to explain complex behaviour in as parsimonious and elegant manner as possible. Future work in the modelling of winning performance ought to further examine the potential of these models. Two of them (catastrophe and chaos) will need specialist mathematical knowledge to push forward understanding. No attempt was made in this research to enter that level of sophistication that distinguishes fad from scientific endeavour.

Alchemy was once a university discipline. The quest for a method to transform base metal into gold has a longer history than the attempt to model winning performance in invasive games but possibly shares the same animus! The trinity of description, modelling and prediction was noted in Chapter One as an important element in notational analysis. Prediction is the logical outcome of the attempt to model performance.

Franks and McGarry (1996) have indicated their desire to use stochastic models of performance to predict outcomes in squash games. Some time ago, Fuller (1988) attempted to predict winning performance in netball. Earlier still Charles Reep predicted outcomes in association football. The urge to predict (and control) is a fundamental aspect of notational analysis. In this study the ideal type models provide the opportunity to predict winning performance within games and between games. They have been formulated through empirical warrant and can be challenged by empirical investigation.

In the years to come, sports scientists will have increasing opportunities to develop probabilistic models of performance. This can be a fundamental research issue and or an applied one. As with other aspects of scientific endeavour, the ability to successfully predict and clone winning performance will raise some very interesting ethical questions.

6.6 Future Research

The research reports work undertaken in just two gender-specific invasive team field games. At an early stage of the research process, it was decided to delimit the study to these games (rugby union and association football). One obvious requirement in future research will be to extend the number of games investigated.

It is vital that the research agenda address gender equity. Although notational analysis has occasionally generated female oriented research it has replicated most other areas of sports science in valorising male activity and reportage by males. It is interesting to note that one of the early influential figures in match analysis was Celia Brackenridge at Sheffield Polytechnic. An immediate step that could be taken is to replicate this work in women's rugby union and association football. The Centre for Notational

Analysis at UWIC has three research project underway in the analysis of performance in women's sports.

Further research could also examine in greater depth any of the investigations discussed in Chapter Four, particularly the possible catastrophic, chaotic, critical incident patterns that exist within invasive team games and the sequence of events in any one match. Such work would enrich what is known about winning performance and further develop models of performance.

Most important of all, future research could set out to develop a language of performance that transcends disciplinary and gender boundaries. It might be expected of a notational analyst to argue that the observation and analysis of performance is central to the development of performance! But this seems essential. This realisation might lead to what Arthur Koestler (1975) has called bisociative vision:

> a sudden leap of the creative imagination which connects two hitherto unrelated ideas, observations, frames of perception or 'universes of discourse' in a new synthesis. It is usually followed by an inaudible Eureka cry which combines intellectual illumination and emotional catharsis.

This seems an appropriate challenge for anyone wanting to further develop the modelling of winning performance in invasive team games.

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Appendix A

Statistical Tables

Table A1: Significance levels for the Chi Square Distribution (Source Fowlie, J.S. (1969), Statistical Tables for Students, London: Oliver and Boyd)

Degrees of Freedom	.99	.95	.90
1	$.0^{3}157$	.00393	.0158
2	.0201	.103	.211
3	.115	.352	.584
4	.297	.711	1.06
5	.554	1.15	1.61
6	.872	1.64	2.20
7	1.24	2.17	2.83
8	1.65	2.73	3.49
9	2.09	3.33	4.17
10	2.56	3.94	4.86
20	8.26	10.85	12.44
30	14.95	18.49	20.60
35	18.51	22.47	24.80

Table A2: Significance levels for Spearman Rank Correlation Coefficients (Source: Fisher, G.H. (1965), The New Form Statistical Tables, London: University of London Press.)

	Significance Level (one-tailed test)	
n	**0.05**	**0.01**
4	1.000	
5	0.900	1.000
6	0.829	0.943
7	0.714	0.893
8	0.643	0.833
9	0.600	0.783
10	0.564	0.746
12	0.506	0.712
14	0.456	0.645
16	0.425	0.601
18	0.399	0.564
20	0.377	0.534
22	0.359	0.508
24	0.343	0.485
26	0.329	0.465
28	0.317	0.448
30	0.306	0.432

Appendix B

Reliability and Validity

The researcher and a fully, trained observer notated the Denmark v Germany match from the 1992 European Soccer Championship Finals and the Wales v South Africa rugby union match (1994). Tests were carried out on the inter- and intra- reliability of both hand and computer systems. The calculations, results and plots are shown in tables B1 to B14 and figures B1 to B39.

Table B1: Intra-reliability test of the hand-notation system: Denmark v Germany

No	Variable	A	B	No	Variable	A	B
1	Denmark Free-kicks conceded (1st Half)	13	12	27	Germany Off-sides (1st half)	3	3
2	Denmark Fouls (1st half)	12	11	28	Germany Hand-balls (1st half)	0	0
3	Denmark Off-sides (1st half)	1	1	29	Germany Throws (2nd Half)	12	12
4	Denmark Hand-balls (1st half)	0	0	30	Germany Corners (2nd Half)	5	5
5	Denmark Throws (1st Half)	8	8	31	Germany Injuries (2nd Half)	0	0
6	Denmark Corners (1st Half)	3	3	32	Germany Goal-kicks (2nd Half)	2	1
7	Denmark Injuries (1st Half)	1	2	33	Denmark GK Long (1st half)	18	20
8	Denmark Goal-kicks (1st Half)	2	2	34	Denmark GK Short (1st half)	8	10
9	Germany Free-kicks conceded (1st Half)	11	11	35	Germany GK Long (1st half)	2	2
10	Germany Fouls (1st half)	7	7	36	Germany GK Short (1st half)	6	8
11	Germany Off-sides (1st half)	4	4	37	Denmark GK Long (1st half)	10	15
12	Germany Hand-balls (1st half)	0	0	38	Denmark GK Short (1st half)	2	4
13	Germany Throws (1st Half)	8	10	39	Germany GK Long (1st half)	2	8
14	Germany Corners (1st Half)	5	5	40	Germany GK Short (1st half)	8	8
15	Germany Injuries (1st Half)	1	1	41	Denmark Shots On target (1st half)	0	1
16	Germany Goal-kicks (1st Half)	3	4	42	Denmark Shots Off target (1st half)	3	2
17	Denmark Free-kicks conceded (2nd Half)	13	12	43	Denmark Goals (1st half)	1	1
18	Denmark Fouls (2nd half)	11	10	44	Germany Shots On target (1st half)	6	6
19	Denmark Off-sides (2nd half)	2	2	45	Germany Shots Off target (1st half)	1	2
20	Denmark Hand-balls (2nd half)	0	0	46	Germany Goals (1st half)	0	0
21	Denmark Throws (2nd Half)	4	5	47	Denmark Shots On target (2nd half)	0	0
22	Denmark Corners (2nd Half)	1	1	48	Denmark Shots Off target (2nd half)	3	3
23	Denmark Injuries (2nd Half)	4	4	49	Denmark Goals (2nd half)	1	1
24	Denmark Goal-kicks (2nd Half)	5	6	50	Germany Shots On target (2nd half)	1	1
25	Germany Free-kicks conceded (2nd Half)	15	16	51	Germany Shots Off target (2ndhalf)	7	6
26	Germany Fouls (1st half)	12	13	52	Germany Goals (2nd half)	0	0

No	Variable	A	B	No	Variable	A	B
1	Denmark Passes (1st Half)	117	127	3	Denmark Passes (2nd Half)	69	69
2	Germany Passes (1st Half)	159	175	4	Germany Passes (2nd Half)	177	178

Table B2: Scott's Pi Coefficient for hand notation system: Denmark v Germany

Category A	Category B	A as % of SUM	B as % of SUM	% difference	(mean %) sq
13	12	1.6905072	1.4669927	0.2235145	0.0249245
12	11	1.5604681	1.3447433	0.2157249	0.0211006
1	1	0.130039	0.1222494	0.0077896	0.0001591
0	0	0	0	0	0
8	8	1.0403121	0.9779951	0.062317	0.0101839
3	3	0.390117	0.3667482	0.0233689	0.0014321
1	2	0.130039	0.2444988	0.1144598	0.0003507
2	2	0.260078	0.2444988	0.0155792	0.0006365
11	11	1.4304291	1.3447433	0.0856859	0.019254
7	7	0.9102731	0.8557457	0.0545274	0.0077971
4	4	0.520156	0.4889976	0.0311585	0.002546
0	0	0	0	0	0
8	10	1.0403121	1.2224939	0.1821818	0.0128007
5	5	0.6501951	0.6112469	0.0389481	0.0039781
1	1	0.130039	0.1222494	0.0077896	0.0001591
3	4	0.390117	0.4889976	0.0988805	0.0019321
13	12	1.6905072	1.4669927	0.2235145	0.0249245
11	10	1.4304291	1.2224939	0.2079352	0.017595
2	2	0.260078	0.2444988	0.0155792	0.0006365
0	0	0	0	0	0
4	5	0.520156	0.6112469	0.0910909	0.0032002
1	1	0.130039	0.1222494	0.0077896	0.0001591
4	4	0.520156	0.4889976	0.0311585	0.002546
5	6	0.6501951	0.7334963	0.0833013	0.0047865
15	16	1.9505852	1.9559902	0.005405	0.0381533
12	13	1.5604681	1.5892421	0.0287739	0.0248017
3	3	0.390117	0.3667482	0.0233689	0.0014321
0	0	0	0	0	0
12	12	1.5604681	1.4669927	0.0934755	0.0229138
5	5	0.6501951	0.6112469	0.0389481	0.0039781
0	0	0	0	0	0
2	1	0.260078	0.1222494	0.1378286	0.0003654
18	20	2.3407022	2.4449878	0.1042856	0.0572571
8	10	1.0403121	1.2224939	0.1821818	0.0128007
2	2	0.260078	0.2444988	0.0155792	0.0006365
6	8	0.7802341	0.9779951	0.197761	0.0077284
10	15	0.00013	0.0001834	5.334E-05	2.456E-10
2	4	0.260078	0.4889976	0.2289195	0.0014028
2	8	0.260078	0.9779951	0.7179171	0.0038321
8	8	1.0403121	0.9779951	0.062317	0.0101839
0	1	0	0.1222494	0.1222494	3.736E-05
3	2	0.390117	0.2444988	0.1456183	0.0010068
1	1	0.130039	0.1222494	0.0077896	0.0001591
6	6	0.7802341	0.7334963	0.0467377	0.0057284
1	2	1.7241379	3.4482759	1.7241379	0.0668847
0	0	0	0	0	0
0	0	0	0	0	0
3	3	0.390117	0.3667482	0.0233689	0.0014321
1	1	0.130039	0.1222494	0.0077896	0.0001591
1	1	0.130039	0.1222494	0.0077896	0.0001591
7	6	0.9102731	0.7334963	0.1767767	0.0067549
0	0	0	0	0	0
117	127	15.214564	15.525672	0.311108	2.3624054
159	175	20.676203	21.393643	0.7174402	4.4246798
69	69	8.9726918	8.4352078	0.537484	0.7575874
177	178	23.016905	21.760391	1.2565139	5.0125157
769	**818**	**100.29384**	**101.37022**	**8.7439133**	**12.986098**

1. Using Scott's Pi Coefficient of Reliability

pi = Po - Pe / 100 - Pe where: Po is the proportion of interobserver agreement, Pe is the proportion of agreement that is expected by chance, Pe is determined by squaring the percent of tallies in each category and summing these over the category

pi = (100.83203 - 8.7439133) - 12.986086 / 100 - 12.986086
pi = 79.102019 / 87.013914
pi = **0.9091**

2. Using Agreements/Disagreements

Number of Agreements / Number of Agreements + Number of Disagreements * 100

Number of Agreements: 762 Number of Disagreements 63

= 762/(762+ 63) * 100
= 762/825 * 100
= 0.9236363 * 100
= **92.3636**

3. Using Simple Plots

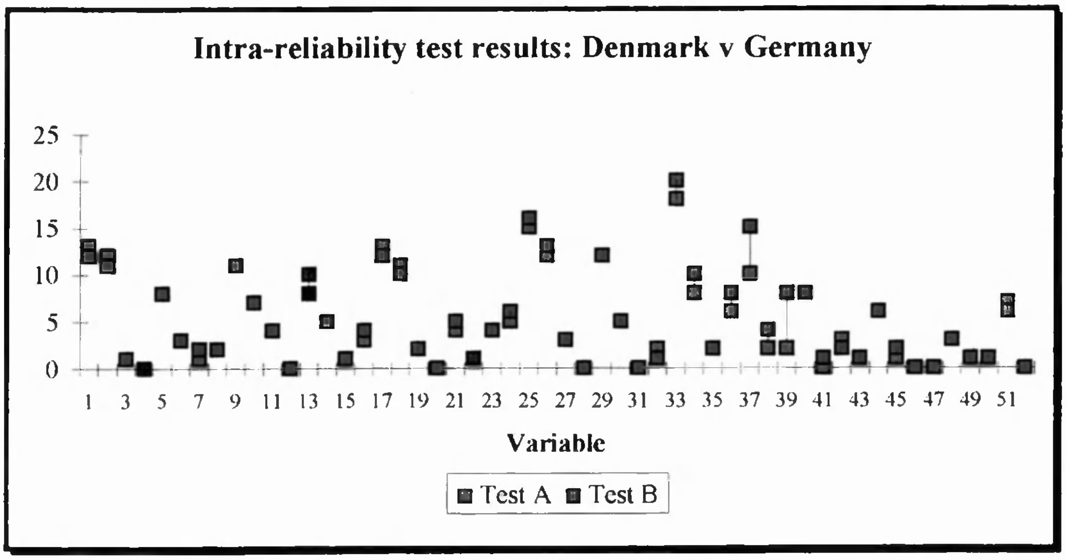

Figure B1: Plots of intra-reliability test for hand notation: Denmark v Germany

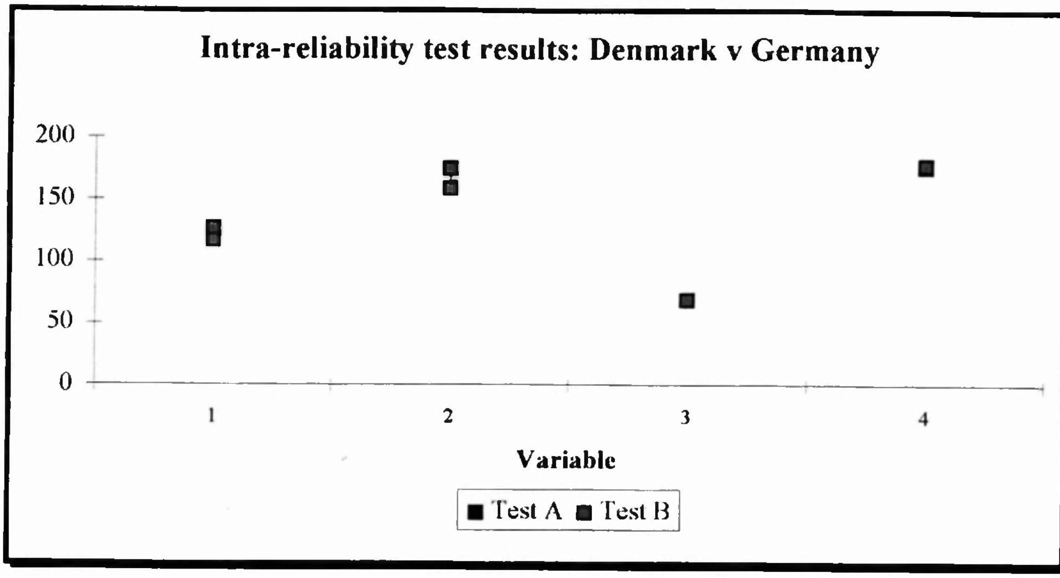

Figure B2: Plots of intra-reliability test for hand notation: Denmark v Germany

Table B3 (a): Intra-reliability test of the hand notation system: Wales v South Africa.

No	Variable	A	B
1	Match Time (1st half)	42:35	42:35
2	Match Time (2nd half)	41:10	41:09
3	Ball in Play Time (1st half)	11:52	11:58
4	Ball in Play Time (2nd half)	13:41	13:17
5	Wales Territorial Time (1st half)	22:01	22:56
6	Wales Territorial Time (2nd half)	19:26	19:52
7	S Africa Territorial Time (1st half)	20:34	19:39
8	S Africa Territorial Time (2nd half)	21:44	21:17
No	**Variable**	**A**	**B**
1	Wales Kicks (1st half)	35	34
2	Wales Kicks (2nd half)	24	24
3	S Africa Kicks (1st half)	24	25
4	S Africa Kicks (2nd half)	22	18
5	Wales Passes (1st half)	58	50
6	Wales Passes (2nd half)	54	51
7	S Africa Passes (1st half)	30	28
8	S Africa Passes (2nd half)	26	32
No	**Variable**	**A**	**B**
1	Wales Line-Outs (1st half)	12	12
2	Wales Line-Outs Won (1st half)	10	10
3	Wales Line-Outs Lost (1st half)	1	1
4	Wales Line-Outs Penalty for (1st half)	1	1
5	Wales Line-Outs Free-kick for (1st half)	0	0
6	Wales Line-Outs Penalty against (1st half)	0	0
7	Wales Line-Outs Free-kick against (1st half)	0	0
8	Wales Line-Outs Not straight/Not 5m (1st half)	0	0
9	Wales Line-Outs Knock-ons (1st half)	0	0
10	S Africa Line-Outs (1st half)	16	16
11	S Africa Line-Outs Won (1st half)	8	8
12	S Africa Line-Outs Lost (1st half)	3	3
13	S Africa Line-Outs Penalty for (1st half)	1	1
14	S Africa Line-Outs Free-kick for (1st half)	1	1
15	S Africa Line-Outs Penalty against (1st half)	1	1
16	S Africa Line-Outs Free-kick against (1st half)	2	2
17	S Africa Line-Outs Not straight/Not 5m (1st half)	0	0
18	S Africa Line-Outs Knock-ons (1st half)	0	0
19	Wales Line-Outs (2nd half)	9	10
20	Wales Line-Outs Won (2nd half)	9	10
21	Wales Line-Outs Lost (2nd half)	0	0

Table B3 (b): Intra-reliability test of the hand notation system: Wales v South Africa.

No	Variable	A	B
22	Wales Line-Outs Penalty for (2nd half)	0	0
23	Wales Line-Outs Free-kick for (2nd half)	0	0
24	Wales Line-Outs Penalty against (2nd half)	0	0
25	Wales Line-Outs Free-kick against (2nd half)	0	0
26	Wales Line-Outs Not straight/Not 5m (2nd half)	0	0
27	Wales Line-Outs Knock-ons (2nd half)	0	0
28	S Africa Line-Outs (2nd half)	12	12
29	S Africa Line-Outs Won (2nd half)	9	9
30	S Africa Line-Outs Lost (2nd half)	3	3
31	S Africa Line-Outs Penalty for (2nd half)	0	0
32	S Africa Line-Outs Free-kick for (2nd half)	0	0
33	S Africa Line-Outs Penalty against (2nd half)	0	0
34	S Africa Line-Outs Free-kick against (2nd half)	0	0
35	S Africa Line-Outs Not straight/Not 5m (2nd half)	0	0
36	S Africa Line-Outs Knock-ons (2nd half)	0	0
No	**Variable**	**A**	**B**
1	Wales Scrums (1st half)	7	7
2	Wales Scrums Won (1st half)	5	4
3	Wales Scrums Lost (1st half)	0	0
4	Wales Scrums Penalty for (1st half)	0	1
5	Wales Scrums Free-kick for (1st half)	0	0
6	Wales Scrums Penalty against (1st half)	0	0
7	Wales Scrums Free-kick against (1st half)	0	0
8	Wales Scrums Collapsed/Disengaged (1st half)	0	0
9	Wales Scrums Wheeled 90 (1st half)	2	2
10	S Africa Scrums (1st half)	8	8
11	S Africa Scrums Won (1st half)	3	3
12	S Africa Scrums Lost (1st half)	1	1
13	S Africa Scrums Penalty for (1st half)	0	0
14	S Africa Scrums Free-kick for (1st half)	0	0
15	S Africa Scrums Penalty against (1st half)	0	0
16	S Africa Scrums Free-kick against (1st half)	1	1
17	S Africa Scrums Collapsed/Disengaged (1st half)	2	2
18	S Africa Scrums Wheeled 90 (1st half)	1	1
19	Wales Scrums (2nd half)	3	3
20	Wales Scrums Won (2nd half)	3	3
21	Wales Scrums Lost (2nd half)	0	0
22	Wales Scrums Penalty for (2nd half)	0	0
23	Wales Scrums Free-kick for (2nd half)	0	0

Table B3 (c): Intra-reliability test of the hand notation system: Wales v South Africa.

No	Variable	A	B
24	Wales Scrums Penalty against (2nd half)	0	0
25	Wales Scrums Free-kick against (2nd half)	0	0
26	Wales Scrums Collapsed/Disengaged (2nd half)	0	0
27	Wales Scrums Wheeled 90 (2nd half)	0	0
28	S Africa Scrums (2nd half)	6	6
29	S Africa Scrums Won (2nd half)	5	5
30	S Africa Scrums Lost (2nd half)	0	0
31	S Africa Scrums Penalty for (2nd half)	0	0
32	S Africa Scrums Free-kick for (2nd half)	0	0
33	S Africa Scrums Penalty against (2nd half)	0	0
34	S Africa Scrums Free-kick against (2nd half)	1	1
35	S Africa Scrums Collapsed/Disengaged (2nd half)	0	0
36	S Africa Scrums Wheeled 90 (2nd half)	0	0
No	**Variable**	**A**	**B**
1	Wales Rucks/Mauls Won (1st half)	12	17
2	Wales Rucks/Mauls Lost/Opp Scrum (1st half)	0	0
3	S Africa Rucks/Mauls Won (1st half)	12	12
4	S Africa Rucks/Mauls Lost/Opp Scrum(1st half)	3	3
5	Wales Rucks/Mauls Won (2nd half)	18	19
6	Wales Rucks/Mauls Lost/Opp Scrum (2nd half)	6	3
7	S Africa Rucks/Mauls Won (2nd half)	17	15
8	S Africa Rucks/Mauls Lost/Opp Scrum (2nd half)	4	2
No	**Variable**	**A**	**B**
1	Wales Tackles Made (1st Half)	23	28
2	Wales Tackles Made (2nd Half)	32	37
3	S Africa Tackles Made (1st Half)	29	36
4	S Africa Tackles Made (2nd Half)	28	39
5	Wales Tackles Missed (1st Half)	6	6
6	Wales Tackles Missed (2nd Half)	5	3
7	S Africa Tackles Missed (1st Half)	4	4
8	S Africa Tackles Missed (2nd Half)	6	4
No	**Variable**	**A**	**B**
1	Wales Goal-kicks Successful	4	4
2	Wales Goal-kicks Unsuccessful	1	1
3	S Africa Goal-kicks Successful	2	2
4	S Africa Goal-kicks Unsuccessful	5	5
5	Wales Restarts Successful	2	5
6	Wales Restarts Unsuccessful	5	3
7	S Africa Restarts Successful	3	4
8	S Africa Restarts Unsuccessful	2	1

Table B3 (d): Intra-reliability test of the hand notation system: Wales v South Africa.

No	Variable	A	B
1	Wales Knock-ons (1st half)	4	4
2	Wales Missed Touch Kicks (1st Half)	1	1
3	Wales Kicks Out on Full (1st Half)	3	3
4	Wales Forward Passes (1st Half)	0	0
5	Wales Knock-ons (2nd half)	4	4
6	Wales Missed Touch Kicks (2nd Half)	0	0
7	Wales Kicks Out on Full (2nd Half)	1	1
8	Wales Forward Passes (2nd Half)	0	0
9	S Africa Knock-ons (1st half)	3	2
10	S Africa Missed Touch Kicks (1st Half)	0	0
11	S Africa Kicks Out on Full (1st Half)	0	0
12	S Africa Forward Passes (1st Half)	0	0
13	S Africa Knock-ons (2nd half)	3	3
14	S Africa Missed Touch Kicks (2nd Half)	0	0
15	S Africa Kicks Out on Full (2nd Half)	0	1
16	S Africa Forward Passes (2nd Half)	0	0
No	**Variable**	**A**	**B**
1	Wales Free-kicks/Penalties Conceded (1st half)	10	9
2	S Africa Free-kicks/Penalties Conceded (1st half)	13	13
3	Wales Free-kicks/Penalties Conceded (2nd half)	6	6
4	S Africa Free-kicks/Penalties Conceded (2nd half)	5	5

Table B4 (a): Scott's Pi Coefficient for hand notation system: Wales v South Africa.

Category A	Category B	A as % of SUM	B as % of SUM	% difference	(mean %) sq
35	34	5.079826	4.836415	0.24341	0.24583
24	24	3.483309	3.41394	0.069369	0.11893
24	25	3.483309	3.556188	0.07288	0.123886
22	18	3.193033	2.560455	0.632578	0.082757
58	50	8.417997	7.112376	1.305622	0.602981
54	51	7.837446	7.254623	0.582823	0.569426
30	28	4.354136	3.98293	0.371206	0.173767
26	32	3.773585	4.55192	0.77834	0.173285
12	12	1.741655	1.70697	0.034684	0.029733
10	10	1.451379	1.422475	0.028904	0.020648
1	1	0.145138	0.142248	0.00289	0.000206
1	1	0.145138	0.142248	0.00289	0.000206
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
16	16	2.322206	2.27596	0.046246	0.052858
8	8	1.161103	1.13798	0.023123	0.013214
3	3	0.435414	0.426743	0.008671	0.001858
1	1	0.145138	0.142248	0.00289	0.000206
1	1	0.145138	0.142248	0.00289	0.000206
1	1	0.145138	0.142248	0.00289	0.000206
2	2	0.290276	0.284495	0.005781	0.000826
0	0	0	0	0	0
0	0	0	0	0	0
9	10	1.306241	1.422475	0.11623	0.018615
9	10	1.306241	1.422475	0.11623	0.018615
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
12	12	1.741655	1.70697	0.034684	0.029733
9	9	1.306241	1.280228	0.026013	0.016725
3	3	0.435414	0.426743	0.008671	0.001858
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
7	7	1.015965	0.995733	0.020233	0.010117
5	4	0.725689	0.56899	0.156699	0.00419
0	0	0	0	0	0
0	1	0	0.142248	0.14225	5.06E-05
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
2	2	0.290276	0.284495	0.005781	0.000826
8	8	1.161103	1.13798	0.023123	0.013214
3	3	0.435414	0.426743	0.008671	0.001858
1	1	0.145138	0.142248	0.00289	0.000206
0	0	0	0	0	0
0	0	0	0	0	0

Table B4 (b): Scott's Pi Coefficient for hand notation system: Wales v South Africa.

Category A	Category B	A as % of SUM	B as % of SUM	% difference	(mean %) sq
0	0	0	0	0	0
1	1	0.145138	0.142248	0.00289	0.000206
2	2	0.290276	0.284495	0.005781	0.000826
1	1	0.145138	0.142248	0.00289	0.000206
3	3	0.435414	0.426743	0.008671	0.001858
3	3	0.435414	0.426743	0.008671	0.001858
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
12	17	1.741655	2.418208	0.67655	0.043261
0	0	0	0	0	0
12	12	1.741655	1.70697	0.034684	0.029733
3	3	0.435414	0.426743	0.008671	0.001858
18	19	2.612482	2.702703	0.09022	0.070628
6	3	0.870827	0.426743	0.444085	0.004209
17	15	2.467344	2.133713	0.333631	0.052924
4	2	0.580552	0.284495	0.296057	0.001871
23	28	3.338171	3.98293	0.64476	0.133996
32	37	4.644412	5.263158	0.61875	0.2454
29	36	4.208999	5.12091	0.91191	0.217618
28	39	4.063861	5.547653	1.48379	0.230953
6	6	0.870827	0.853485	0.017342	0.007433
5	3	0.725689	0.426743	0.298947	0.00332
4	4	0.580552	0.56899	0.011561	0.003304
6	4	0.870827	0.56899	0.301837	0.005183
4	4	0.580552	0.56899	0.011561	0.003304
1	1	0.145138	0.142248	0.00289	0.000206
3	3	0.435414	0.426743	0.008671	0.001858
0	0	0	0	0	0
4	4	0.580552	0.56899	0.011561	0.003304
0	0	0	0	0	0
1	1	0.145138	0.142248	0.00289	0.000206
0	0	0	0	0	0
3	2	0.435414	0.284495	0.150919	0.001296
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
3	3	0.435414	0.426743	0.008671	0.001858
0	0	0	0	0	0
0	1	0	0.142248	0.14225	5.06E-05
0	0	0	0	0	0
4	4	0.580552	0.56899	0.011561	0.003304
1	1	0.145138	0.142248	0.00289	0.000206
2	2	0.290276	0.284495	0.005781	0.000826
5	5	0.725689	0.711238	0.014452	0.005162
2	5	1.724138	4.310345	2.58621	0.091037
5	3	0.725689	0.426743	0.298947	0.00332
3	4	0.435414	0.56899	0.13358	0.002522
2	1	0.290276	0.142248	0.148028	0.000468
10	9	1.451379	1.280228	0.171151	0.018654
13	13	1.886792	1.849218	0.037575	0.034894
6	6	0.870827	0.853485	0.017342	0.007433
5	5	0.725689	0.711238	0.014452	0.005162
689	**703**	**101.4339**	**103.5991**	**14.86264**	**3.568758**

1. Using Scott's Pi Coefficient of Reliability

pi = Po - Pe / 100 - Pe   where: Po is the proportion of interobserver agreement, Pe is the proportion of agreement that is expected by chance, Pe is determined by squaring the percent of tallies in each category and summing these over the category

pi = (102.51649 - 14.86264) - 3.568758 / 100 - 3.568758
pi = 84.085087 / 96.431242
pi = **0.8720**

2. Using Agreements/Disagreements calculations

Number of Agreements / Number of Agreements + Number of Disagreements * 100

Number of Agreements:	668
Number of Disagreements	84

= 668 /(668 + 84) * 100
= 668/752 * 100
= 0.9095744 * 100
= **90.95744**

3. Using Simple Plots

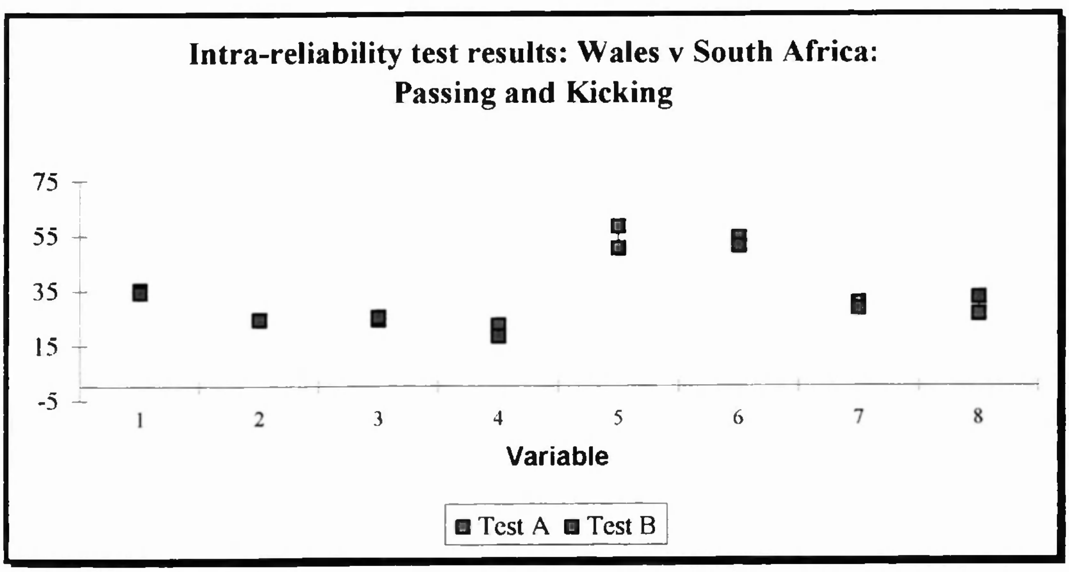

Figure B3: Plots of intra-reliability test for hand notation: Wales v South Africa

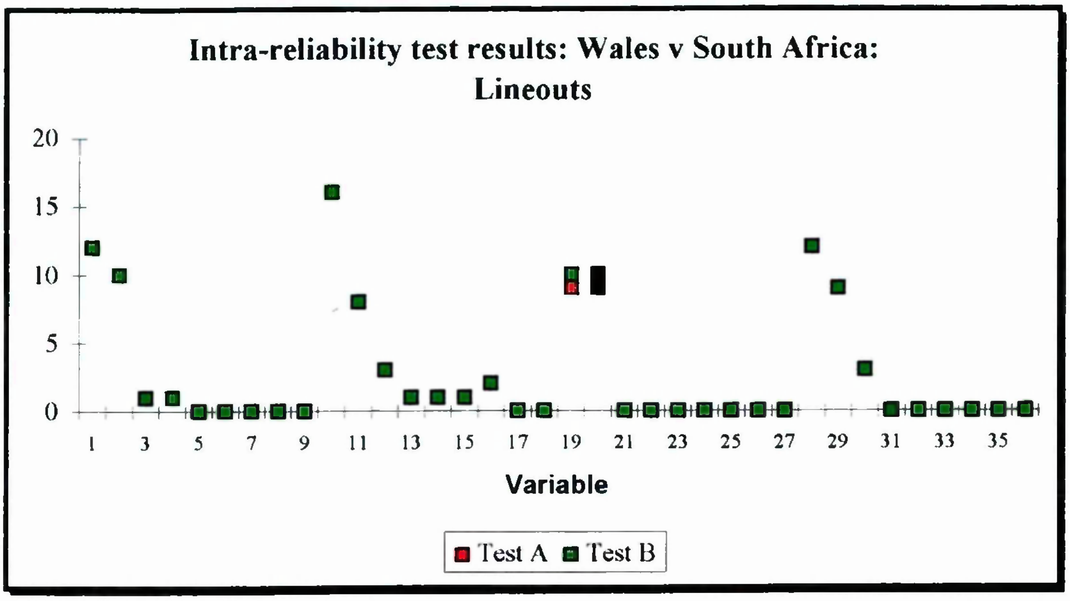

Figure B4: Plots of intra-reliability test for hand notation: Wales v South Africa

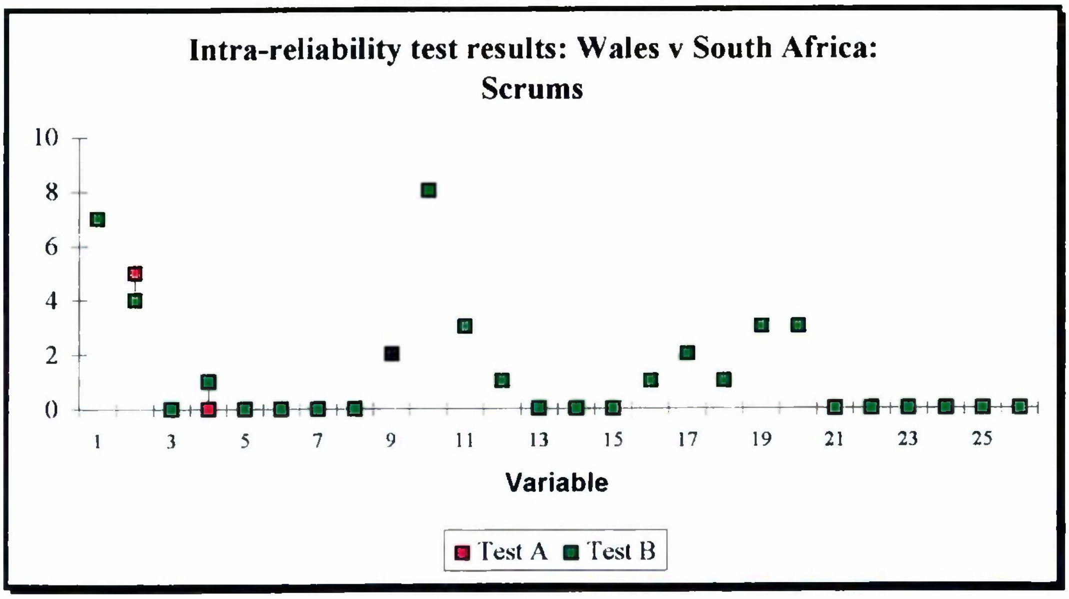

Figure B5: Plots of intra-reliability test for hand notation: Wales v South Africa

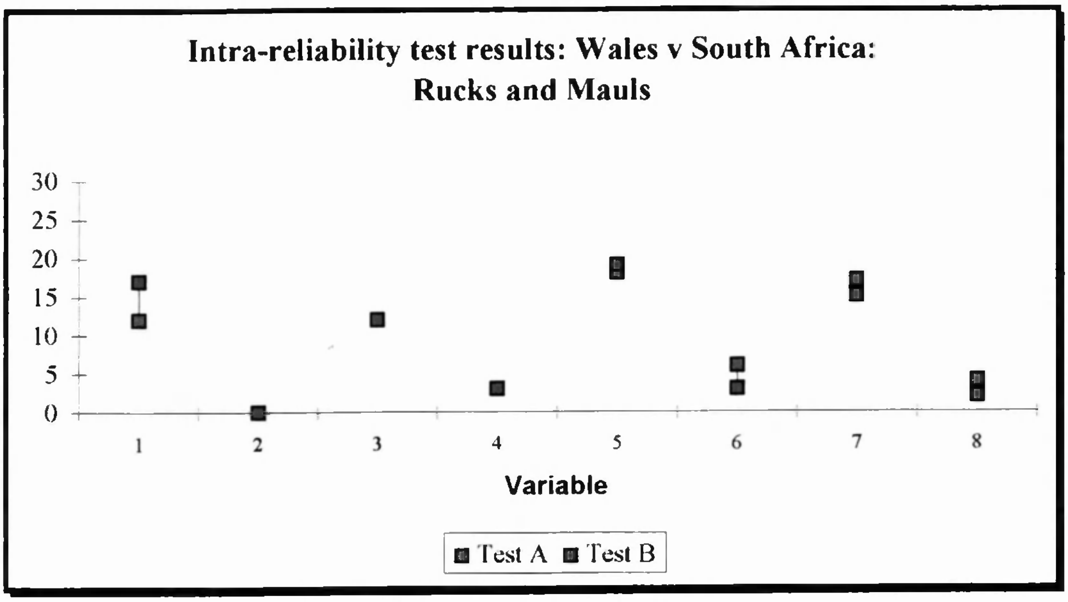

Figure B6: Plots of intra-reliability test for hand notation: Wales v South Africa

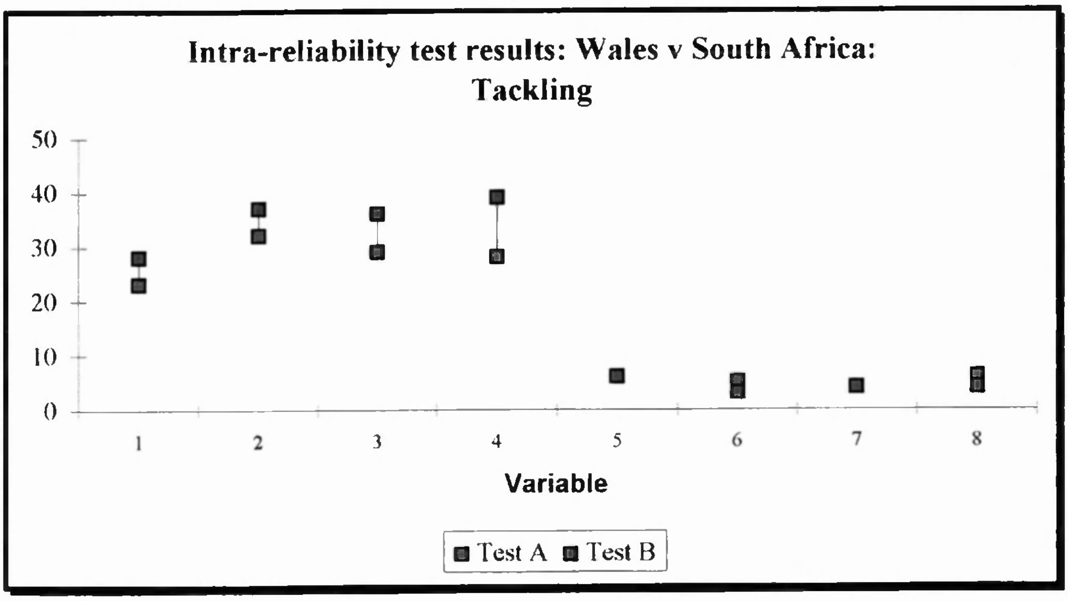

Figure B7: Plots of intra-reliability test for hand notation: Wales v South Africa

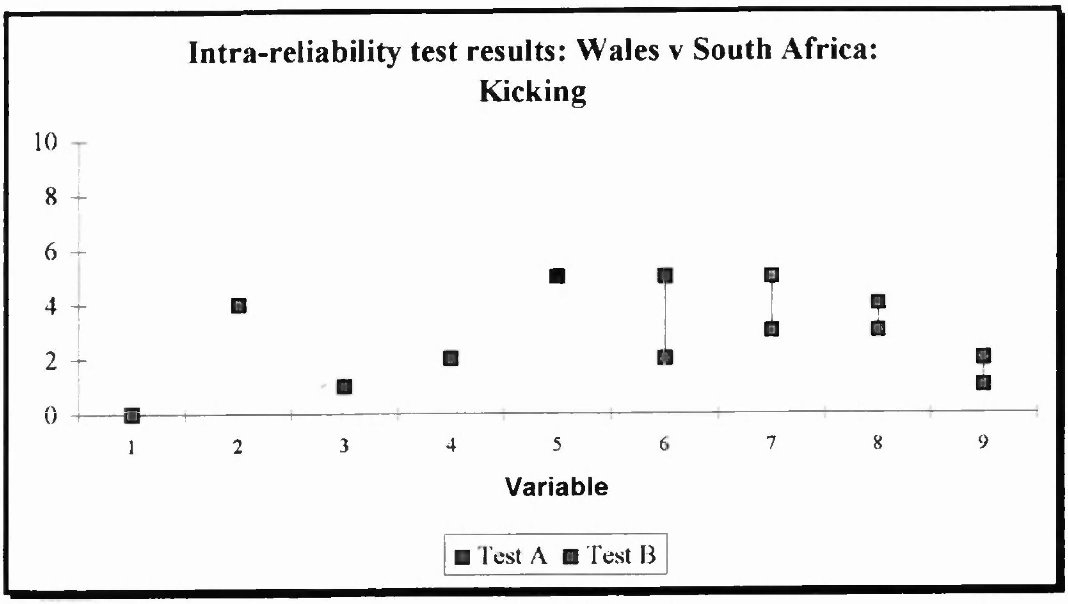

Figure B8: Plots of intra-reliability test for hand notation: Wales v South Africa

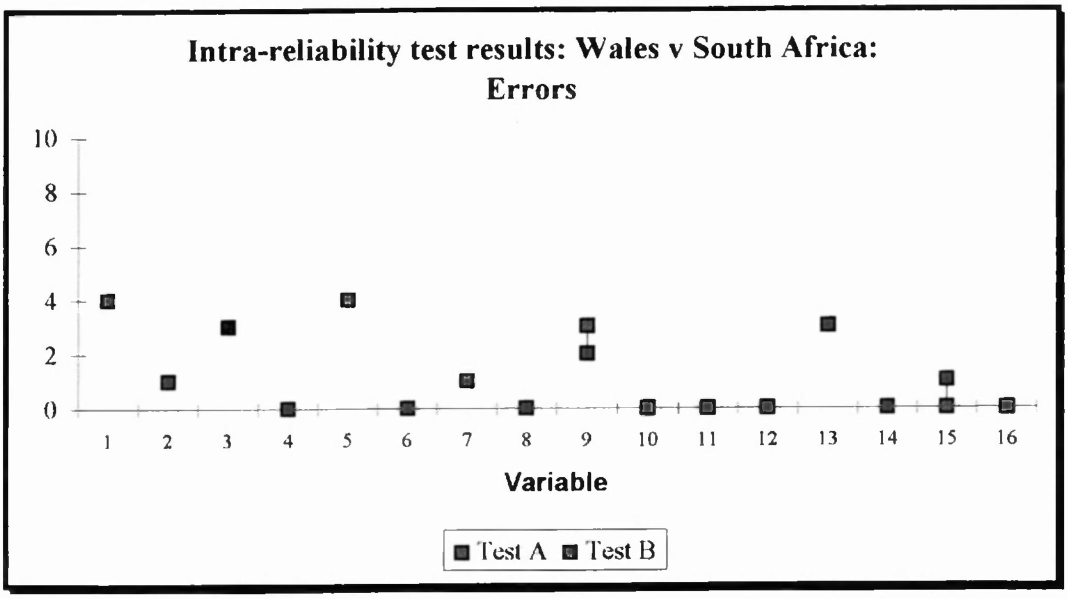

Figure B9: Plots of intra-reliability test for hand notation: Wales v South Africa

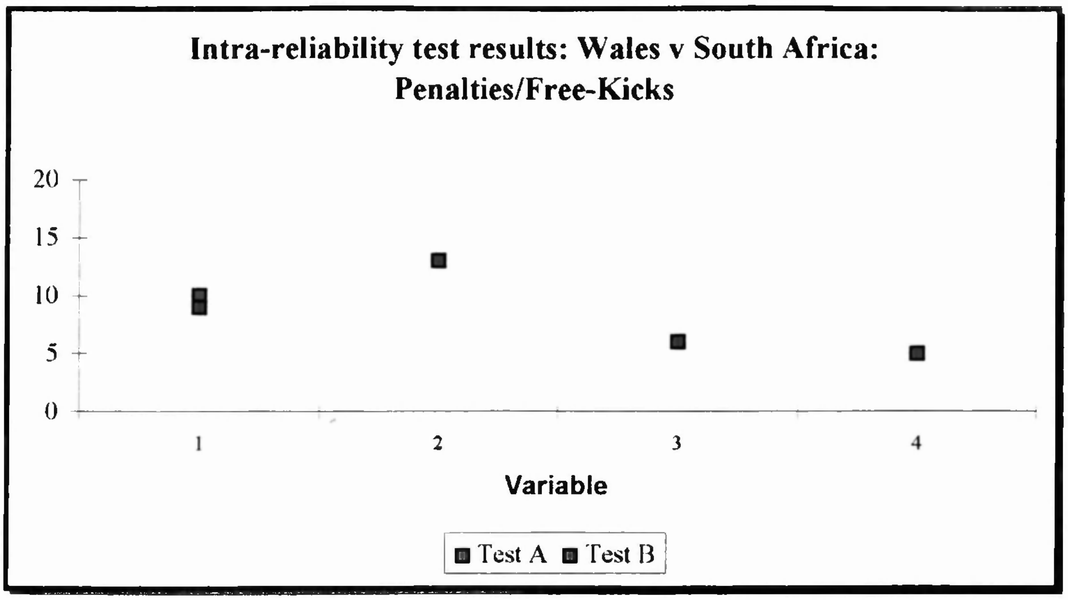

Figure B10: Plots of intra-reliability test for hand notation: Wales v South Africa

Table B5 (a): Intra-reliability test of the hand-notation system: Denmark v Germany

	Variable	A	B
1	Match Time (1st half)	46:13	46:12
2	Match Time (2nd half)	46:09	46:08
3	Ball in Play Time (1st half)	29:44	29:40
4	Ball in Play Time (2nd half)	25:43	25:32
5	Denmark Territorial Time (1st half)	19:20	19:35
6	Denmark Territorial Time (2nd half)	16:04	15:50
7	Germany Territorial Time (1st half)	26:53	26:37
8	Germany Territorial Time (2nd half)	30:05	30:18
9	Denmark Possession Time (1st half)	15:14	15:22
10	Denmark Possession Time (2nd half)	09:51	09:50
11	Germany Possession Time (1st half)	14:25	14:18
12	Germany Possession Time (2nd half)	15:42	15:42
13	Activity Cycles (1st half)	56	56
14	Activity Cycles (2nd half)	58	59
	Variable	**A**	**B**
1	Denmark in Opp Pen Area (1st half)	12	12
2	Denmark in Opp Pen Area (2nd half)	12	12
3	Germany in Opp Pen Area (1st half)	27	26
4	Germany in Opp Pen Area (2nd half)	41	40
5	Denmark Goals (1st half)	1	1
6	Denmark Goals (2nd half)	1	1
7	Germany Goals (1st half)	0	0
8	Germany Goals (2nd half)	0	0
	Variable	**A**	**B**
1	Denmark Throw-Ins (1st half)	8	8
2	Denmark Throw-Ins Retained (1st half)	5	5
3	Denmark Throw-Ins Lost (1st half)	3	3
4	Denmark Throw-Ins Free-kick for (1st half)	0	0
5	Denmark Throw-Ins Free-kick against (1st half)	0	0
6	Denmark Throw-Ins Foul Throw (1st half)	0	0
7	Denmark Throw-Ins Indeterminate (1st half)	0	0
8	Denmark Throw-Ins (2nd half)	5	5
9	Denmark Throw-Ins Retained (2nd half)	3	3
10	Denmark Throw-Ins Lost (2nd half)	1	1
11	Denmark Throw-Ins Free-kick for (2nd half)	1	1
12	Denmark Throw-Ins Free-kick against (2nd half)	0	0
13	Denmark Throw-Ins Foul Throw (2nd half)	0	0
14	Denmark Throw-Ins Indeterminate (2nd half)	0	0
15	Germany Throw-Ins (1st half)	8	8

Table B5 (b): Intra-reliability test of the hand-notation system: Denmark v Germany

	Variable	A	B
16	Germany Throw-Ins Retained (1st half)	8	7
17	Germany Throw-Ins Lost (1st half)	0	1
18	Germany Throw-Ins Free-kick for (1st half)	0	0
19	Germany Throw-Ins Free-kick against (1st half)	0	0
20	Germany Throw-Ins Foul Throw (1st half)	0	0
21	Germany Throw-Ins Indeterminate (1st half)	0	0
22	Germany Throw-Ins (2nd half)	13	13
23	Germany Throw-Ins Retained (2nd half)	12	12
24	Germany Throw-Ins Lost (2nd half)	1	1
25	Germany Throw-Ins Free-kick for (2nd half)	0	0
26	Germany Throw-Ins Free-kick against (2nd half)	0	0
27	Germany Throw-Ins Foul Throw (2nd half)	0	0
28	Germany Throw-Ins Indeterminate (2nd half)	0	0
	Variable	**A**	**B**
1	Denmark Goal-keeper Possessions For (1st half)	31	31
2	Denmark Goal-keeper Possessions Retained (1st half)	19	20
3	Denmark Goal-keeper Possessions Lost (1st half)	11	10
4	Denmark Goal-keeper Possessions Free-kick For (1st half)	0	0
5	Denmark Goal-keeper Possessions Free-kick Against (1st half)	1	1
6	Denmark Goal-keeper Possessions Indeterminate (1st half)	0	0
7	Denmark Goal-keeper Possessions For (2nd half)	17	17
8	Denmark Goal-keeper Possessions Retained (2nd half)	3	3
9	Denmark Goal-keeper Possessions Lost (2nd half)	13	12
10	Denmark Goal-keeper Possessions Free-kick For (2nd half)	1	1
11	Denmark Goal-keeper Possessions Free-kick Against (2nd half)	0	0
12	Denmark Goal-keeper Possessions Indeterminate (2nd half)	0	0
13	Germany Goal-keeper Possessions For (1st half)	11	11
14	Germany Goal-keeper Possessions Retained (1st half)	9	8
15	Germany Goal-keeper Possessions Lost (1st half)	1	2
16	Germany Goal-keeper Possessions Free-kick For (1st half)	0	0
17	Germany Goal-keeper Possessions Free-kick Against (1st half)	1	1
18	Germany Goal-keeper Possessions Indeterminate (1st half)	0	0
19	Germany Goal-keeper Possessions For (2nd half)	11	11
20	Germany Goal-keeper Possessions Retained (2nd half)	9	10
21	Germany Goal-keeper Possessions Lost (2nd half)	2	1
22	Germany Goal-keeper Possessions Free-kick For (2nd half)	0	0
23	Germany Goal-keeper Possessions Free-kick Against (2nd half)	0	0
24	Germany Goal-keeper Possessions Indeterminate (2nd half)	0	0

Table B5 (c): Intra-reliability test of the hand-notation system: Denmark v Germany

	Variable	A	B
1	Denmark Passes Attempted (1st half)	159	155
2	Denmark Passes Retained (1st half)	117	115
3	Denmark Passes Lost (1st half)	42	40
4	Denmark Passes Attempted (2nd half)	105	105
5	Denmark Passes Retained (2nd half)	77	75
6	Denmark Passes Lost (2nd half)	28	30
7	Germany Passes Attempted (1st half)	219	214
8	Germany Passes Retained (1st half)	168	163
9	Germany Passes Lost (1st half)	51	51
10	Germany Passes Attempted (2nd half)	231	230
11	Germany Passes Retained (2nd half)	190	189
12	Germany Passes Lost (2nd half)	41	41
	Variable	**A**	**B**
1	Denmark Free-kicks/Penalties Conceded in Own PA (1st half)	0	0
2	Denmark Free-kicks/Penalties Conceded in Own Half (1st half)	6	6
3	Denmark Free-kicks/Penalties Conceded in Opp Half (1st half)	7	7
4	Denmark Free-kicks/Penalties Conceded in Own PA (2nd half)	0	0
5	Denmark Free-kicks/Penalties Conceded in Own Half (2nd half)	7	7
6	Denmark Free-kicks/Penalties Conceded in Opp Half (2nd half)	6	6
7	Germany Free-kicks/Penalties Conceded in Own PA (1st half)	0	0
8	Germany Free-kicks/Penalties Conceded in Own Half (1st half)	1	1
9	Germany Free-kicks/Penalties Conceded in Opp Half (1st half)	10	11
10	Germany Free-kicks/Penalties Conceded in Own PA (2nd half)	0	0
11	Germany Free-kicks/Penalties Conceded in Own Half (2nd half)	6	5
12	Germany Free-kicks/Penalties Conceded in Opp Half (2nd half)	8	8
	Variable	**A**	**B**
1	Denmark Shots Successful (1st half)	1	1
2	Denmark Shots Unsuccessful (1st half)	2	2
3	Denmark Headers Successful (1st half)	0	0
4	Denmark Headers Unsuccessful (1st half)	0	0
5	Denmark Shots Successful (2nd half)	1	2
6	Denmark Shots Unsuccessful (2nd half)	3	2
7	Denmark Headers Successful (2nd half)	0	0
8	Denmark Headers Unsuccessful (2nd half)	0	0
9	Germany Shots Successful (1st half)	6	6
10	Germany Shots Unsuccessful (1st half)	1	1
11	Germany Headers Successful (1st half)	0	0
12	Germany Headers Unsuccessful (1st half)	1	1
13	Germany Shots Successful (2nd half)	1	1
14	Germany Shots Unsuccessful (2nd half)	4	4
15	Germany Headers Successful (2nd half)	1	1
16	Germany Headers Unsuccessful (2nd half)	1	1

Table B5 (d): Intra-reliability test of the hand-notation system: Denmark v Germany

No	Variable	A	B
1	Denmark Crosses Successful (1st half)	0	0
2	Denmark Crosses Unsuccessful (1st half)	3	3
3	Denmark Corners Successful (1st half)	1	1
4	Denmark Corners Unsuccessful (1st half)	2	1
5	Denmark Crosses Successful (2nd half)	0	0
6	Denmark Crosses Unsuccessful (2nd half)	5	5
7	Denmark Corners Successful (2nd half)	0	0
8	Denmark Corners Unsuccessful (2nd half)	1	1
9	Germany Crosses Successful (1st half)	2	2
10	Germany Crosses Unsuccessful (1st half)	10	10
11	Germany Corners Successful (1st half)	2	2
12	Germany Corners Unsuccessful (1st half)	3	3
13	Germany Crosses Successful (2nd half)	9	8
14	Germany Crosses Unsuccessful (2nd half)	13	14
15	Germany Corners Successful (2nd half)	0	0
16	Germany Corners Unsuccessful (2nd half)	5	5

1. Using Scott's Pi Coefficient of Reliability

pi = Po - Pe / 100 - Pe

where: Po is the proportion of interobserver agreement
Pe is the proportion of agreement that is expected by chance
Pe is determined by squaring the percent of tallies in each category and summing these all over the category

pi = (100.27146 - 2.0984314) - 6.8202835 / 100 - 6.8202835
pi = 98.173024 - 6.8202835 / 93.179717
pi = 91.35274 / 93.179717
pi = **0.9803929**

2. Using Agreements/Disagreements

Number of Agreements / Number of Agreements + Number of Disagreements * 100
Number of Agreements: 1826 Number of Disagreements 40

= 1826/(1826+ 40) * 100
= 1826/1866* 100
= 0.9785637 * 100
= **97.85637**

Table B6: Scott's Pi Coefficient for the computer system: Denmark v Germany

Category A	Category B	A as % of SUM	B as % of SUM	% difference	(mean %) sq
12	12	0.6472492	0.6557377	0.0084885	0.0042444
12	12	0.6472492	0.6557377	0.0084885	0.0042444
27	26	1.4563107	1.420765	0.0355457	0.0206939
41	40	2.2114347	2.1857923	0.0256424	0.048339
1	1	0.0539374	0.0546448	0.0007074	2.948E-05
1	1	0.0539374	0.0546448	0.0007074	2.948E-05
0	0	0	0	0	0
0	0	0	0	0	0
8	8	0.4314995	0.4371585	0.005659	0.0018864
5	5	0.2696872	0.273224	0.0035369	0.0007369
3	3	0.1618123	0.1639344	0.0021221	0.0002653
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
5	5	0.2696872	0.273224	0.0035369	0.0007369
3	3	0.1618123	0.1639344	0.0021221	0.0002653
1	1	0.0539374	0.0546448	0.0007074	2.948E-05
1	1	0.0539374	0.0546448	0.0007074	2.948E-05
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
8	8	0.4314995	0.4371585	0.005659	0.0018864
8	7	0.4314995	0.3825137	0.0489858	0.0016565
0	1	0	0.0546448	0.0546448	7.465E-06
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
13	13	0.7011866	0.7103825	0.0091959	0.0049813
12	12	0.6472492	0.6557377	0.0084885	0.0042444
1	1	0.0539374	0.0546448	0.0007074	2.948E-05
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
31	31	1.6720604	1.6939891	0.0219287	0.0283257
19	20	1.0248112	1.0928962	0.068085	0.0112117
11	10	0.5933118	0.5464481	0.0468637	0.0032476
0	0	0	0	0	0
1	1	0.0539374	0.0546448	0.0007074	2.948E-05
0	0	0	0	0	0
17	17	0.9169364	0.9289617	0.0120254	0.0085183
3	3	0.1618123	0.1639344	0.0021221	0.0002653
13	12	0.7011866	0.6557377	0.0454489	0.0046031
1	1	0.0539374	0.0546448	0.0007074	2.948E-05
0	0	0	0	0	0
0	0	0	0	0	0
11	11	0.5933118	0.6010929	0.0077811	0.0035665
9	8	0.4854369	0.4371585	0.0482784	0.002128
1	2	0.0539374	0.1092896	0.0553522	6.661E-05
0	0	0	0	0	0
1	1	0.0539374	0.0546448	0.0007074	2.948E-05
0	0	0	0	0	0
11	11	0.5933118	0.6010929	0.0077811	0.0035665
9	10	0.4854369	0.5464481	0.0610112	0.002662
2	1	0.1078749	0.0546448	0.0532301	6.603E-05
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
159	155	8.5760518	8.4699454	0.1061064	0.726415
117	115	6.3106796	6.284153	0.0265266	0.3965745
42	40	2.2653722	2.1857923	0.0795798	0.0495322

105	105	5.6634304	5.7377049	0.0742745	0.3249647
77	75	4.1531823	4.0983607	0.0548217	0.1702199
28	30	1.5102481	1.6393443	0.1290962	0.0247998
219	214	11.812298	11.693989	0.1183087	1.3813638
168	163	9.0614887	8.9071038	0.1543848	0.8071758
51	51	2.7508091	2.7868852	0.0360762	0.0766651
231	230	12.459547	12.568306	0.1087591	1.5659836
190	189	10.248112	10.327869	0.0797567	1.0584275
41	41	2.2114347	2.2404372	0.0290024	0.0495479
0	0	0	0	0	0
6	6	0.3236246	0.3278689	0.0042443	0.0010611
7	7	0.377562	0.3825137	0.0049516	0.0014443
0	0	0	0	0	0
7	7	0.377562	0.3825137	0.0049516	0.0014443
6	6	0.3236246	0.3278689	0.0042443	0.0010611
0	0	0	0	0	0
1	1	0.0539374	0.0546448	0.0007074	2.948E-05
10	11	0.5393743	0.6010929	0.0617186	0.0032517
0	0	0	0	0	0
6	5	0.3236246	0.273224	0.0504006	0.0008906
8	8	0.4314995	0.4371585	0.005659	0.0018864
1	1	0.0539374	0.0546448	0.0007074	2.948E-05
2	2	0.1078749	0.1092896	0.0014148	0.0001179
0	0	0	0	0	0
0	0	0	0	0	0
1	2	0.0539374	0.1092896	0.0553522	6.661E-05
3	2	0.1618123	0.1092896	0.0525227	0.0001837
0	0	0	0	0	0
0	0	0	0	0	0
6	6	0.3236246	0.3278689	0.0042443	0.0010611
1	1	0.0539374	0.0546448	0.0007074	2.948E-05
0	0	0	0	0	0
1	1	0.0539374	0.0546448	0.0007074	2.948E-05
1	1	0.0539374	0.0546448	0.0007074	2.948E-05
4	4	0.2157497	0.2185792	0.0028295	0.0004716
1	1	0.0539374	0.0546448	0.0007074	2.948E-05
1	1	0.0539374	0.0546448	0.0007074	2.948E-05
0	0	0	0	0	0
3	3	0.1618123	0.1639344	0.0021221	0.0002653
1	1	0.0539374	0.0546448	0.0007074	2.948E-05
2	1	0.1078749	0.0546448	0.0532301	6.603E-05
0	0	0	0	0	0
5	5	0.2696872	0.273224	0.0035369	0.0007369
0	0	0	0	0	0
1	1	0.0539374	0.0546448	0.0007074	2.948E-05
2	2	0.1078749	0.1092896	0.0014148	0.0001179
10	10	0.5393743	0.5464481	0.0070738	0.0029475
2	2	0.1078749	0.1092896	0.0638407	0.0001179
3	3	0.1618123	0.1639344	0.0021221	0.0002653
9	8	0.4854369	0.4371585	0.0482784	0.002128
13	14	0.7011866	0.7650273		0.0053745
0	0	0	0	0	0
5	5	0.2696872	0.273224	0.0035369	0.0007369
1854	**1830**	**100.26969**	**100.27322**	**2.0984314**	**6.8202835**

3. Using Simple Plots

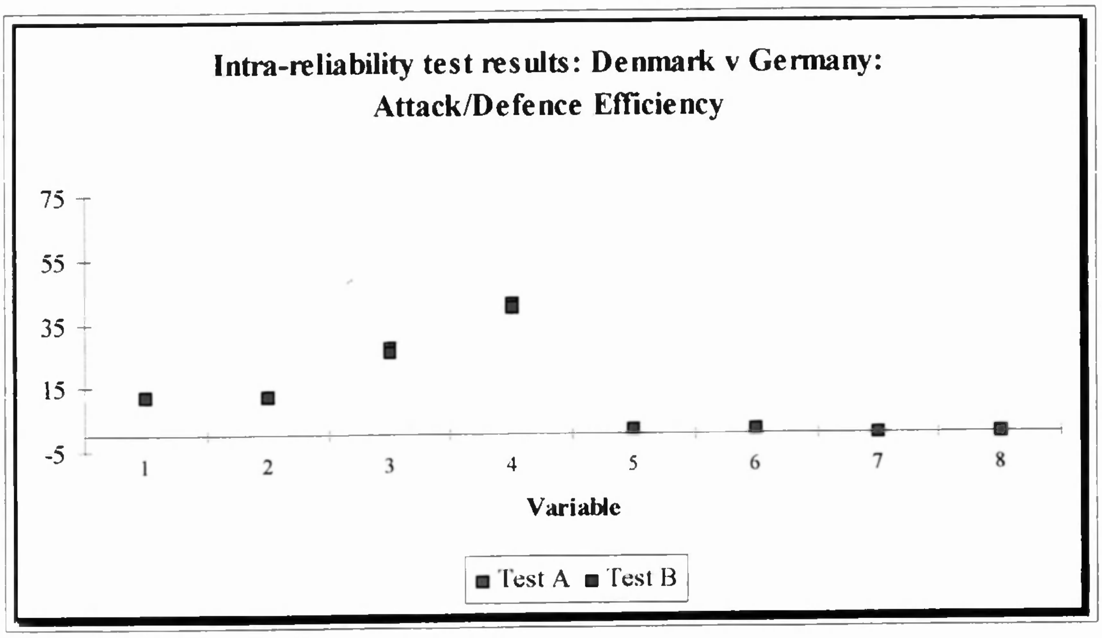

Figure B11: Plots of intra-reliability test for computer notation: Denmark v Germany

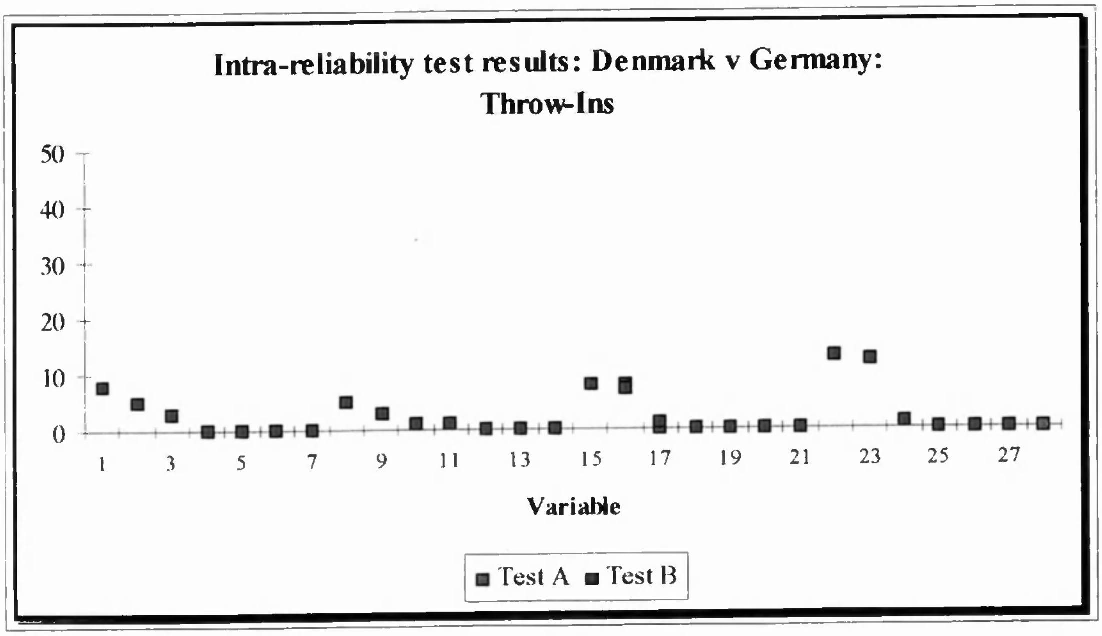

Figure B12: Plots of intra-reliability test for computer notation: Denmark v Germany

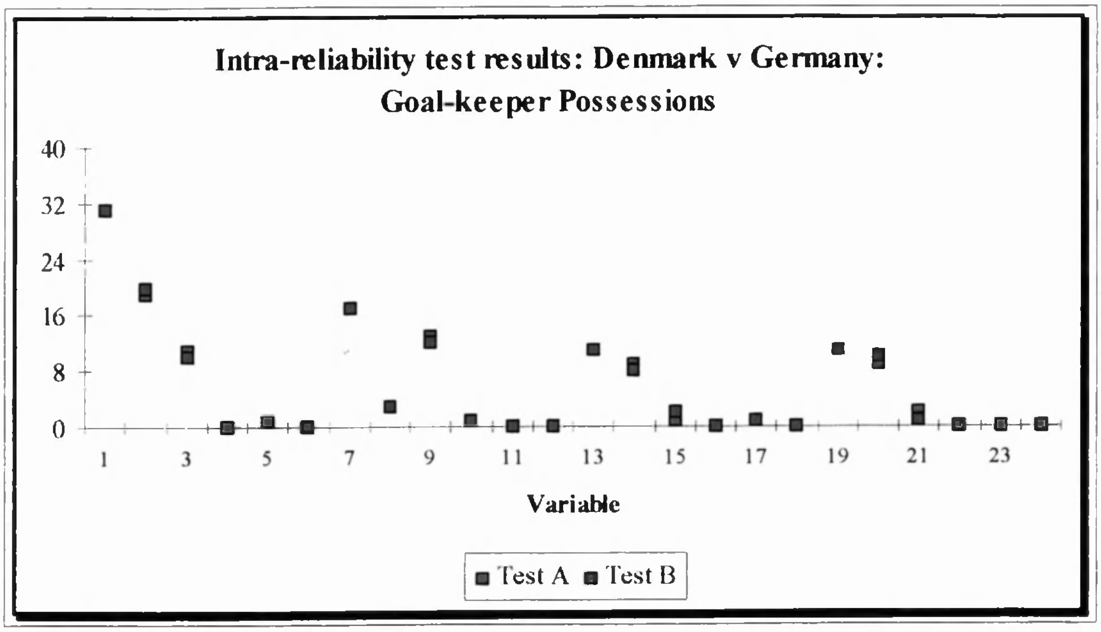

Figure B13: Plots of intra-reliability test for computer notation: Denmark v Germany

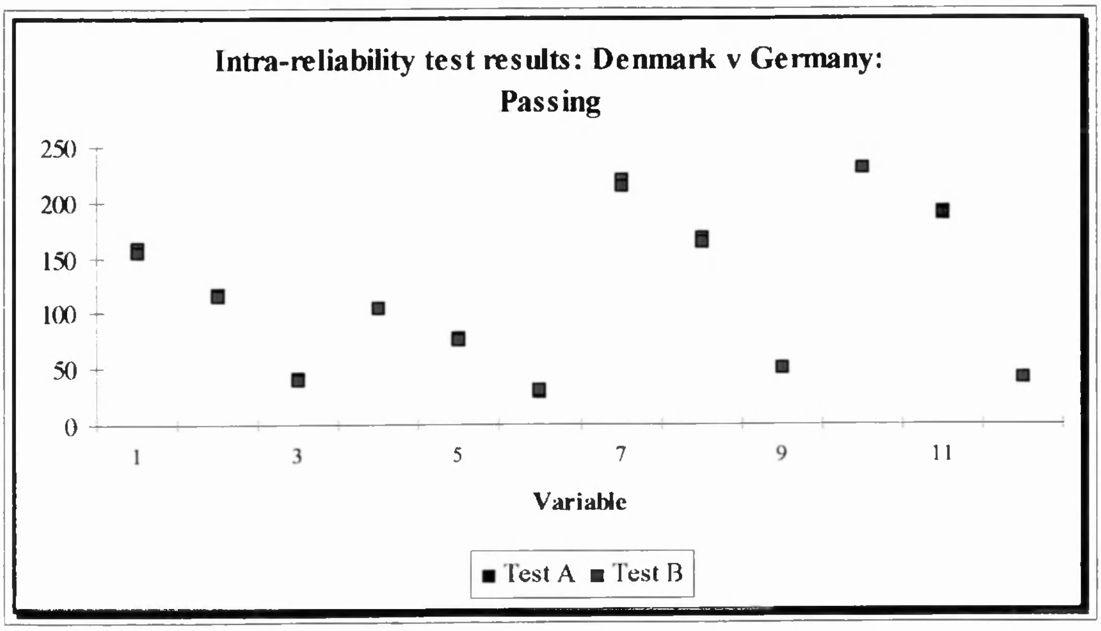

Figure B14: Plots of intra-reliability test for computer notation: Denmark v Germany

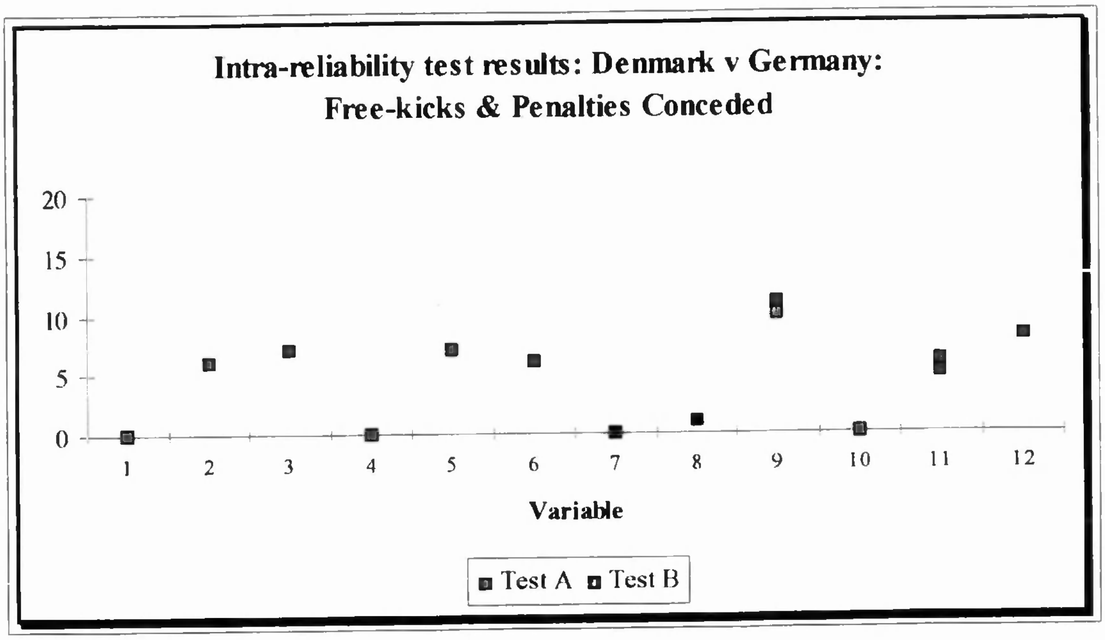

Figure B15: Plots of intra-reliability test for computer notation: Denmark v Germany

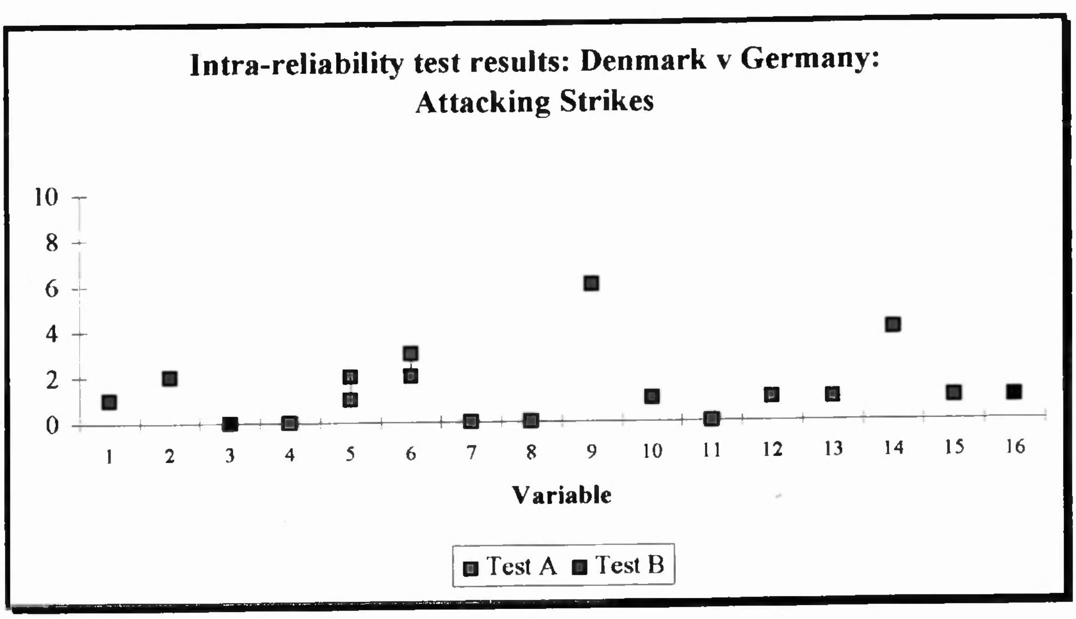

Figure B16: Plots of intra-reliability test for computer notation: Denmark v Germany

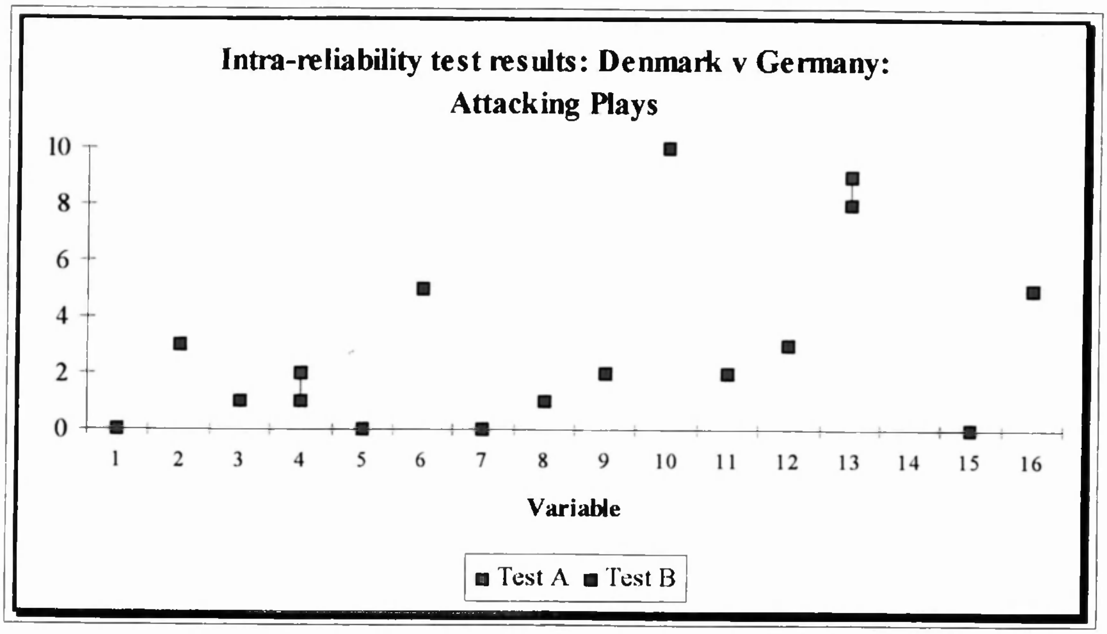

Figure B17: Plots of intra-reliability test for computer notation: Denmark v Germany

Table B7 (a): Intra-reliability test of the computer-notation system: Wales v S Africa

	Variable	A	B
1	Match Time (1st half)	42:39	42:39
2	Match Time (2nd half)	41:11	41:10
3	Ball in Play Time (1st half)	12:23	12:27
4	Ball in Play Time (2nd half)	13:19	13:15
5	Wales Territorial Time (1st half)	23:06	22:56
6	Wales Territorial Time (2nd half)	19:52	20:45
7	S Africa Territorial Time (1st half)	19:33	19:43
8	S Africa Territorial Time (2nd half)	21:19	20:25
9	Wales Possession Time (1st half)	05:00	05:15
10	Wales Possession Time (2nd half)	04:07	04:09
11	S Africa Possession Time (1st half)	06:22	06:25
12	S Africa Possession Time (2nd half)	04:27	04:38
13	Activity Cycles (1st half)	67	67
14	Activity Cycles (2nd half)	51	51
	Variable	**A**	**B**
1	Wales in Opp 22m Area (1st half)	9	10
2	Wales in Opp 22m Area (2nd half)	1	1
3	S Africa in Opp 22m Area (1st half)	3	3
4	S Africa in Opp 22m Area (2nd half)	3	3
5	Wales Tries (1st half)	0	0
6	Wales Tries (2nd half)	0	0
7	S Africa Tries (1st half)	2	2
8	S Africa Tries (2nd half)	1	1
	Variable	**A**	**B**
1	Wales Line-Outs (1st half)	12	12
2	Wales Line-Outs Won (1st half)	10	10
3	Wales Line-Outs Lost (1st half)	1	1
4	Wales Line-Outs Penalty for (1st half)	1	1
5	Wales Line-Outs Free-kick for (1st half)	0	0
6	Wales Line-Outs Penalty against (1st half)	0	0
7	Wales Line-Outs Free-kick against (1st half)	0	0
8	Wales Line-Outs Not straight/Not 5m (1st half)	0	0
9	Wales Line-Outs Knock-ons (1st half)	0	0
10	S Africa Line-Outs (1st half)	16	16
11	S Africa Line-Outs Won (1st half)	8	8
12	S Africa Line-Outs Lost (1st half)	3	3
13	S Africa Line-Outs Penalty for (1st half)	1	1
14	S Africa Line-Outs Free-kick for (1st half)	1	1
15	S Africa Line-Outs Penalty against (1st half)	1	1

Table B7 (b): Intra-reliability test of the computer-notation system: Wales v S Africa

	Variable	A	B
16	S Africa Line-Outs Free-kick against (1st half)	2	2
17	S Africa Line-Outs Not straight/Not 5m (1st half)	0	0
18	S Africa Line-Outs Knock-ons (1st half)	0	0
19	Wales Line-Outs (2nd half)	10	9
20	Wales Line-Outs Won (2nd half)	10	9
21	Wales Line-Outs Lost (2nd half)	0	0
22	Wales Line-Outs Penalty for (2nd half)	0	0
23	Wales Line-Outs Free-kick for (2nd half)	0	0
24	Wales Line-Outs Penalty against (2nd half)	0	0
25	Wales Line-Outs Free-kick against (2nd half)	0	0
26	Wales Line-Outs Not straight/Not 5m (2nd half)	0	0
27	Wales Line-Outs Knock-ons (2nd half)	0	0
28	S Africa Line-Outs (2nd half)	12	12
29	S Africa Line-Outs Won (2nd half)	9	9
30	S Africa Line-Outs Lost (2nd half)	3	3
31	S Africa Line-Outs Penalty for (2nd half)	0	0
32	S Africa Line-Outs Free-kick for (2nd half)	0	0
33	S Africa Line-Outs Penalty against (2nd half)	0	0
34	S Africa Line-Outs Free-kick against (2nd half)	0	0
35	S Africa Line-Outs Not straight/Not 5m (2nd half)	0	0
36	S Africa Line-Outs Knock-ons (2nd half)	0	0
	Variable	**A**	**B**
1	Wales Scrums (1st half)	8	8
2	Wales Scrums Won (1st half)	5	5
3	Wales Scrums Lost (1st half)	1	1
4	Wales Scrums Penalty for (1st half)	0	0
5	Wales Scrums Free-kick for (1st half)	0	0
6	Wales Scrums Penalty against (1st half)	0	0
7	Wales Scrums Free-kick against (1st half)	0	0
8	Wales Scrums Collapsed/Disengaged (1st half)	0	0
9	Wales Scrums Wheeled 90 (1st half)	2	2
10	S Africa Scrums (1st half)	7	7
11	S Africa Scrums Won (1st half)	3	2
12	S Africa Scrums Lost (1st half)	0	0
13	S Africa Scrums Penalty for (1st half)	0	0
14	S Africa Scrums Free-kick for (1st half)	0	0
15	S Africa Scrums Penalty against (1st half)	0	0
16	S Africa Scrums Free-kick against (1st half)	1	1
17	S Africa Scrums Collapsed/Disengaged (1st half)	2	3
18	S Africa Scrums Wheeled 90 (1st half)	1	1
19	Wales Scrums (2nd half)	3	3
20	Wales Scrums Won (2nd half)	3	3
21	Wales Scrums Lost (2nd half)	0	0

Table B7 (c): Intra-reliability test of the computer-notation system: Wales v S Africa

	Variable	A	B
22	Wales Scrums Penalty for (2nd half)	0	0
23	Wales Scrums Free-kick for (2nd half)	0	0
24	Wales Scrums Penalty against (2nd half)	0	0
25	Wales Scrums Free-kick against (2nd half)	0	0
26	Wales Scrums Collapsed/Disengaged (2nd half)	0	0
27	Wales Scrums Wheeled 90 (2nd half)	0	0
28	S Africa Scrums (2nd half)	6	6
29	S Africa Scrums Won (2nd half)	5	5
30	S Africa Scrums Lost (2nd half)	0	0
31	S Africa Scrums Penalty for (2nd half)	0	0
32	S Africa Scrums Free-kick for (2nd half)	0	0
33	S Africa Scrums Penalty against (2nd half)	0	1
34	S Africa Scrums Free-kick against (2nd half)	1	0
35	S Africa Scrums Collapsed/Disengaged (2nd half)	0	0
36	S Africa Scrums Wheeled 90 (2nd half)	0	0
	Variable	**A**	**B**
1	Wales Rucks/Mauls (1st half)	18	19
2	Wales Rucks/Mauls Won (1st half)	14	15
3	Wales Rucks/Mauls Lost (1st half)	0	0
4	Wales Rucks/Mauls Penalty for (1st half)	1	1
5	Wales Rucks/Mauls Free-kick for (1st half)	0	0
6	Wales Rucks/Mauls Penalty against (1st half)	2	2
7	Wales Rucks/Mauls Free-kick against (1st half)	0	0
8	Wales Rucks/Mauls Own Scrum (1st half)	1	1
9	Wales Rucks/Mauls Opp Scrum (1st half)	0	0
10	S Africa Rucks/Mauls (1st half)	17	18
11	S Africa Rucks/Mauls Won (1st half)	11	12
12	S Africa Rucks/Mauls Lost (1st half)	3	3
13	S Africa Rucks/Mauls Penalty for (1st half)	2	2
14	S Africa Rucks/Mauls Free-kick for (1st half)	0	0
15	S Africa Rucks/Mauls Penalty against (1st half)	1	1
16	S Africa Rucks/Mauls Free-kick against (1st half)	0	0
17	S Africa Rucks/Mauls Own Scrum (1st half)	0	0
18	S Africa Rucks/Mauls Opp Scrum (1st half)	0	0
19	Wales Rucks/Mauls (2nd half)	30	28
20	Wales Rucks/Mauls Won (2nd half)	19	17
21	Wales Rucks/Mauls Lost (2nd half)	5	5
22	Wales Rucks/Mauls Penalty for (2nd half)	4	4
23	Wales Rucks/Mauls Free-kick for (2nd half)	0	0
24	Wales Rucks/Mauls Penalty against (2nd half)	1	1
25	Wales Rucks/Mauls Free-kick against (2nd half)	0	0
26	Wales Rucks/Mauls Own Scrum (2nd half)	0	0
27	Wales Rucks/Mauls Opp Scrum (2nd half)	1	1

Table B7 (d): Intra-reliability test of the computer-notation system: Wales v S Africa

No	Variable	A	B
28	S Africa Rucks/Mauls (2nd half)	19	19
29	S Africa Rucks/Mauls Won (2nd half)	13	13
30	S Africa Rucks/Mauls Lost (2nd half)	4	4
31	S Africa Rucks/Mauls Penalty for (2nd half)	1	1
32	S Africa Rucks/Mauls Free-kick for (2nd half)	0	0
33	S Africa Rucks/Mauls Penalty against (2nd half)	0	0
34	S Africa Rucks/Mauls Free-kick against (2nd half)	0	0
35	S Africa Rucks/Mauls Own Scrum (2nd half)	1	1
36	S Africa Rucks/Mauls Opp Scrum (2nd half)	0	0
No	**Variable**	**A**	**B**
1	Wales Goal-kicks Successful (1st half)	2	2
2	Wales Goal-kicks Unsuccessful (1st half)	2	2
3	Wales Touch Successful (1st half)	1	1
4	Wales Touch Unsuccessful (1st half)	4	4
5	Wales Goal-kicks Successful (2nd half)	1	1
6	Wales Goal-kicks Unsuccessful (2nd half)	4	4
7	Wales Touch Successful (2nd half)	6	6
8	Wales Touch Unsuccessful (2nd half)	2	3
9	S Africa Goal-kicks Successful (1st half)	1	1
10	S Africa Goal-kicks Unsuccessful (1st half)	1	1
11	S Africa Touch Successful (1st half)	3	3
12	S Africa Touch Unsuccessful (1st half)	1	1
13	S Africa Goal-kicks Successful (2nd half)	0	0
14	S Africa Goal-kicks Unsuccessful (2nd half)	3	3
15	S Africa Touch Successful (2nd half)	2	2
16	S Africa Touch Unsuccessful (2nd half)	0	0
17	Wales Restarts Successful (1st half)	2	2
18	Wales Restarts Unsuccessful (1st half)	2	2
19	Wales Other Successful (1st half)	7	8
20	Wales Other Unsuccessful (1st half)	5	4
21	Wales Restarts Successful (2nd half)	2	2
22	Wales Restarts Unsuccessful (2nd half)	0	0
23	Wales Other Successful (2nd half)	7	7
24	Wales Other Unsuccessful (2nd half)	2	2
25	S Africa Restarts Successful (1st half)	2	2
26	S Africa Restarts Unsuccessful (1st half)	1	1
27	S Africa Other Successful (1st half)	5	6
28	S Africa Other Unsuccessful (1st half)	8	9
29	S Africa Restarts Successful (2nd half)	2	2
30	S Africa Restarts Unsuccessful (2nd half)	2	2
31	S Africa Other Successful (2nd half)	4	4
32	S Africa Other Unsuccessful (2nd half)	2	2

Table B7 (e): Intra-reliability test of the computer-notation system: Wales v S Africa

No	Variable	A	B
1	Wales Free-kicks/Penalties Conceded in Own 22m(1st half)	2	2
2	Wales Free-kicks/Penalties Conceded in Own 22m-Half Way (1st half)	2	2
3	Wales Free-kicks/Penalties Conceded in Half Way - Opp 22m (1st half)	1	1
4	Wales Free-kicks/Penalties Conceded in Opp 22m (2nd half)	4	4
5	S Africa Free-kicks/Penalties Conceded in Own 22m (1st half)	1	2
6	S Africa Free-kicks/Penalties Conceded in Own 22m-Half Way (1st half)	4	3
7	S Africa Free-kicks/Penalties Conceded in Half Way - Opp 22m (1st half)	6	5
8	S Africa Free-kicks/Penalties Conceded in Opp 22m (2nd half)	2	2
9	Wales Free-kicks/Penalties Conceded in Own 22m (2nd half)	1	1
10	Wales Free-kicks/Penalties Conceded in Own 22m-Half Way (2nd half)	1	1
11	Wales Free-kicks/Penalties Conceded in Half Way - Opp 22m (2nd half)	3	2
12	Wales Free-kicks/Penalties Conceded in Opp 22m (2nd half)	1	1
13	S Africa Free-kicks/Penalties Conceded in Own 22m (2nd half)	0	0
14	S Africa Free-kicks/Penalties Conceded in Own 22m-Half Way (2nd half)	3	2
15	S Africa Free-kicks/Penalties Conceded in Half Way - Opp 22m (2nd half)	2	3
16	S Africa Free-kicks/Penalties Conceded in Opp 22m (2nd half)	0	0

1. Using Scott's Pi Coefficient of Reliability

pi = Po - Pe / 100 - Pe

where: Po is the proportion of interobserver agreement
Pe is the proportion of agreement that is expected by chance
Pe is determined by squaring the percent of tallies in each category and summing these all over the category

pi = (100.52105 - 5.0433346) - 2.1841663 / 100 - 2.1841663
pi = 93.293544 / 97.815834
pi = **0.9937673**

2. Using Agreements/Disagreements calculations

Number of Agreements / Number of Agreements + Number of Disagreements * 100

Number of Agreements: 461 Number of Disagreements 21

= 461/(461+ 21) * 100
= 461/482 * 100
= 0.9564315 * 100
= **95.64315**

Table B8 (a): Scott's Pi Coefficient for computer notation system: Wales v S Africa.

Category A	Category B	A as % of SUM	B as % of SUM	% difference	(mean %) sq
9	10	1.9067797	2.1052632	0.1984835	0.0402412
1	1	0.2118644	0.2105263	0.0013381	0.000446
3	3	0.6355932	0.6315789	0.0040143	0.0040143
3	3	0.6355932	0.6315789	0.0040143	0.0040143
0	0	0	0	0	0
0	0	0	0	0	0
2	2	0.4237288	0.4210526	0.0026762	0.0017841
1	1	0.2118644	0.2105263	0.0013381	0.000446
12	12	2.5423729	2.5263158	0.0160571	0.064229
10	10	2.1186441	2.1052632	0.0133809	0.0446035
1	1	0.2118644	0.2105263	0.0013381	0.000446
1	1	0.2118644	0.2105263	0.0013381	0.000446
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
16	16	3.3898305	3.3684211	0.0214095	0.1141849
8	8	1.6949153	1.6842105	0.0107047	0.0285462
3	3	0.6355932	0.6315789	0.0040143	0.0040143
1	1	0.2118644	0.2105263	0.0013381	0.000446
1	1	0.2118644	0.2105263	0.0013381	0.000446
1	1	0.2118644	0.2105263	0.0013381	0.000446
2	2	0.4237288	0.4210526	0.0026762	0.0017841
0	0	0	0	0	0
0	0	0	0	0	0
10	9	2.1186441	1.8947368	0.2239072	0.0402681
10	9	2.1186441	1.8947368	0.2239072	0.0402681
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
12	12	2.5423729	2.5263158	0.0160571	0.064229
9	9	1.9067797	1.8947368	0.0120428	0.0361288
3	3	0.6355932	0.6315789	0.0040143	0.0040143
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
8	8	1.6949153	1.6842105	0.0107047	0.0285462
5	5	1.059322	1.0526316	0.0066905	0.0111509
1	1	0.2118644	0.2105263	0.0013381	0.000446
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
2	2	0.4237288	0.4210526	0.0026762	0.0017841
7	7	1.4830508	1.4736842	0.0093666	0.0218557
3	2	0.6355932	0.4210526	0.2145406	0.0027913
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
1	1	0.2118644	0.2105263	0.0013381	0.000446
2	3	0.4237288	0.6315789	0.2078501	0.0027842

1	1	0.2118644	0.2105263	0.0013381	0.000446
3	3	0.6355932	0.6315789	0.0040143	0.0040143
3	3	0.6355932	0.6315789	0.0040143	0.0040143
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
6	6	1.2711864	1.2631579	0.0080285	0.0160573
5	5	1.059322	1.0526316	0.0066905	0.0111509
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	1	0	0.2105263	-0.2105263	0.0001108
1	0	0.2118644	0	0.2118644	0.0001122
0	0	0	0	0	0
0	0	0	0	0	0
18	19	3.8135593	4	0.1864407	0.1526293
14	15	2.9661017	3.1578947	0.191793	0.0937583
0	0	0	0	0	0
1	1	0.2118644	0.2105263	0.0013381	0.000446
0	0	0	0	0	0
2	2	0.4237288	0.4210526	0.0026762	0.0017841
0	0	0	0	0	0
1	1	0.2118644	0.2105263	0.0013381	0.000446
0	0	0	0	0	0
17	18	3.6016949	3.7894737	0.1877788	0.1365734
11	12	2.3305085	2.5263158	0.1958073	0.0589719
3	3	0.6355932	0.6315789	0.0040143	0.0040143
2	2	0.4237288	0.4210526	0.0026762	0.0017841
0	0	0	0	0	0
1	1	0.2118644	0.2105263	0.0013381	0.000446
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
30	28	6.3559322	5.8947368	0.4611954	0.3751972
19	17	4.0254237	3.5789474	0.4464764	0.1445661
5	5	1.059322	1.0526316	0.0066905	0.0111509
4	4	0.8474576	0.8421053	0.0053524	0.0071366
0	0	0	0	0	0
1	1	0.2118644	0.2105263	0.0013381	0.000446
0	0	0	0	0	0
0	0	0	0	0	0
1	1	0.6024096	0.862069	0.2596593	0.0053617
19	19	4.0254237	4	0.0254237	0.1610186
13	13	2.7542373	2.7368421	0.0173952	0.0753799
4	4	0.8474576	0.8421053	0.0053524	0.0071366
1	1	0.2118644	0.2105263	0.0013381	0.000446
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
1	1	0.2118644	0.2105263	0.0013381	0.000446
0	0	0	0	0	0
2	2	0.4237288	0.4210526	0.0026762	0.0017841
1	1	0.2118644	0.2105263	0.0013381	0.000446
12	11	2.5423729	2.3157895	0.2265834	0.0590044

1	1	0.2118644	0.2105263	0.0013381	0.000446
2	2	0.4237288	0.4210526	0.0026762	0.0017841
0	0	0	0	0	0
6	7	1.2711864	1.4736842	0.2024978	0.0188358
0	0	0	0	0	0
0	0	0	0	0	0
3	3	0.6355932	0.6315789	0.0040143	0.0040143
10	10	2.1186441	2.1052632	0.0133809	0.0446035
1	2	0.2118644	0.4210526	0.2091882	0.0010015
2	2	0.4237288	0.4210526	0.0026762	0.0017841
2	2	0.4237288	0.4210526	0.0026762	0.0017841
9	9	1.9067797	1.8947368	0.0120428	0.0361288
0	0	0	0	0	0
2	2	0.4237288	0.4210526	0.0026762	0.0017841
2	2	0.4237288	0.4210526	0.0026762	0.0017841
7	8	1.4830508	1.6842105	0.2011597	0.0250789
5	4	1.059322	0.8421053	0.2172168	0.0090386
2	2	0.4237288	0.4210526	0.0026762	0.0017841
0	0	0	0	0	0
7	7	1.4830508	1.4736842	0.0093666	0.0218557
2	2	0.4237288	0.4210526	0.0026762	0.0017841
2	2	0.4237288	0.4210526	0.0026762	0.0017841
1	1	0.2118644	0.2105263	0.0013381	0.000446
5	6	1.059322	1.2631579	0.2038359	0.0134848
8	9	1.6949153	1.8947368	0.1998216	0.032214
2	2	0.4237288	0.4210526	0.0026762	0.0017841
2	2	0.4237288	0.4210526	0.0026762	0.0017841
4	4	0.8474576	0.8421053	0.0053524	0.0071366
2	2	0.4237288	0.4210526	0.0026762	0.0017841
2	2	0.4237288	0.4210526	0.0026762	0.0017841
2	2	0.4237288	0.4210526	0.0026762	0.0017841
1	1	0.2118644	0.2105263	0.0013381	0.000446
4	4	0.8474576	0.8421053	0.0053524	0.0071366
1	1	0.2118644	0.2105263	0.0013381	0.000446
4	4	0.8474576	0.8421053	0.0053524	0.0071366
6	6	1.2711864	1.2631579	0.0080285	0.0160573
2	3	0.4237288	0.6315789	0.2078501	0.0027842
1	1	0.2118644	0.2105263	0.0013381	0.000446
1	1	0.2118644	0.2105263	0.0013381	0.000446
3	3	0.6355932	0.6315789	0.0040143	0.0040143
1	1	0.2118644	0.2105263	0.0013381	0.000446
0	0	0	0	0	0
3	3	0.6355932	0.6315789	0.0040143	0.0040143
2	2	0.4237288	0.4210526	0.0026762	0.0017841
0	0	0	0	0	0
472	**475**	**100.39055**	**100.65154**	**5.0433346**	**2.1841663**

3. Using Simple Plots

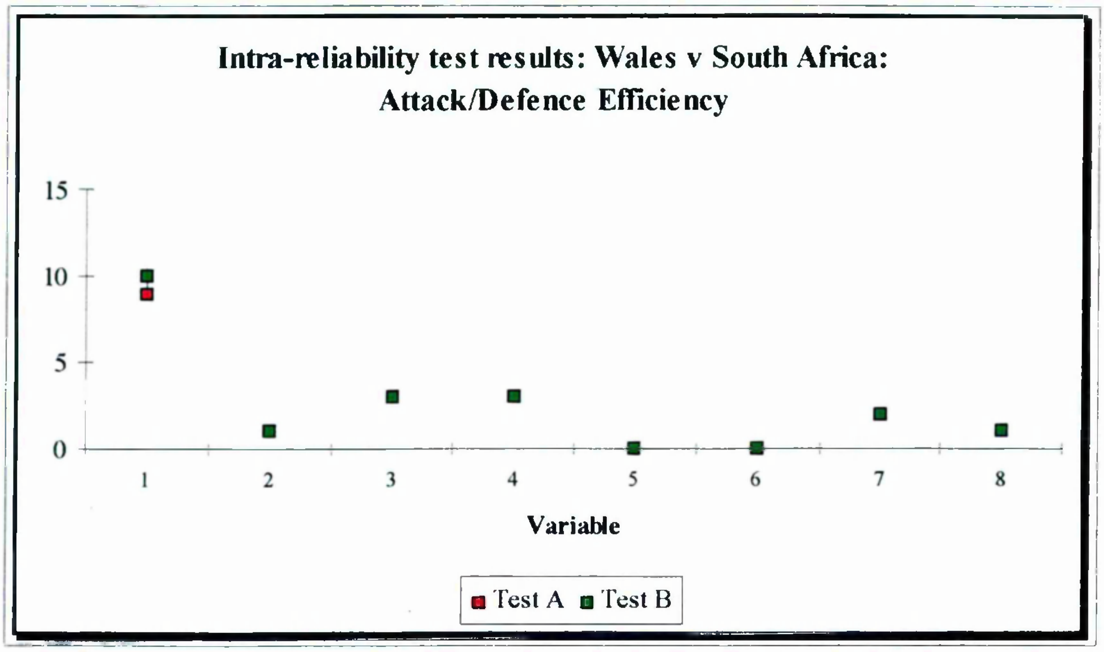

Figure B18: Plots of intra-reliability test for computer notation: Wales v S Africa

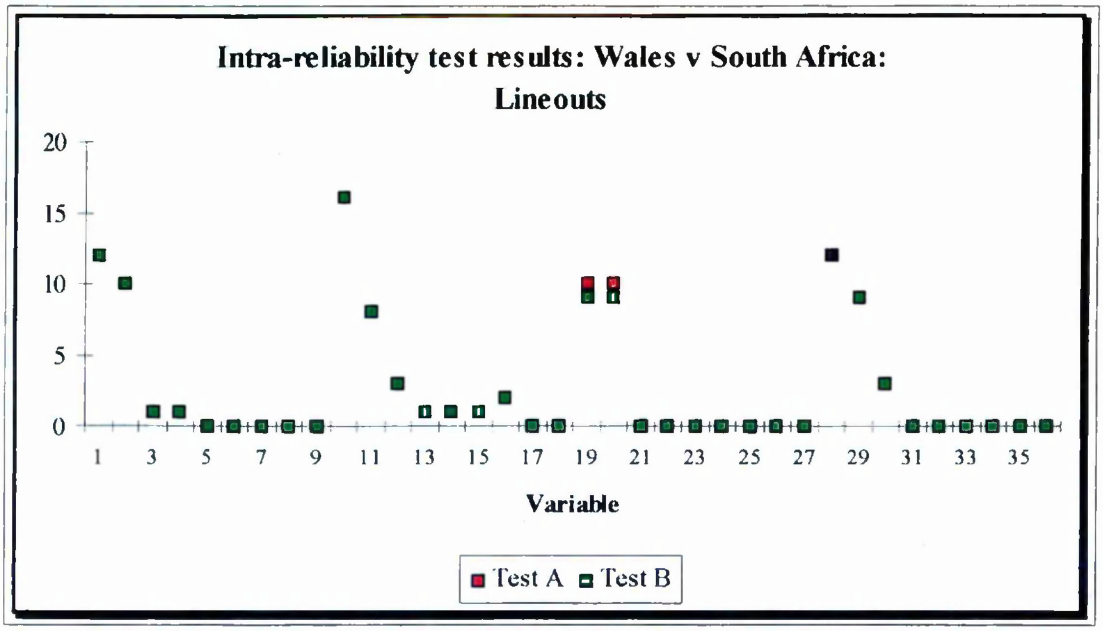

Figure B19: Plots of intra-reliability test for computer notation: Wales v S Africa

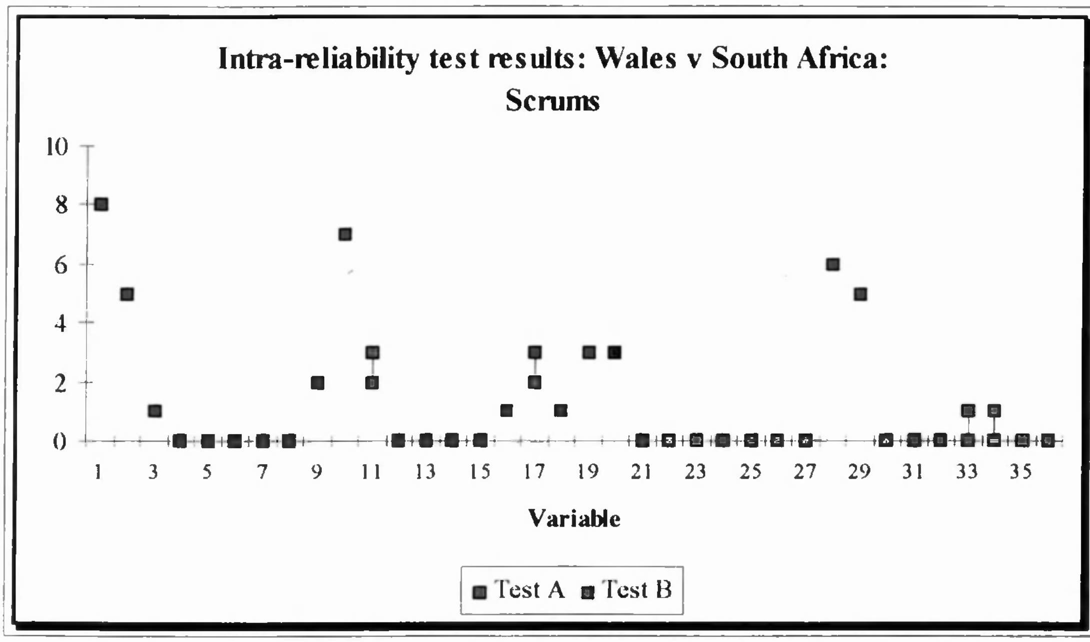

Figure B20: Plots of intra-reliability test for computer notation: Wales v S Africa

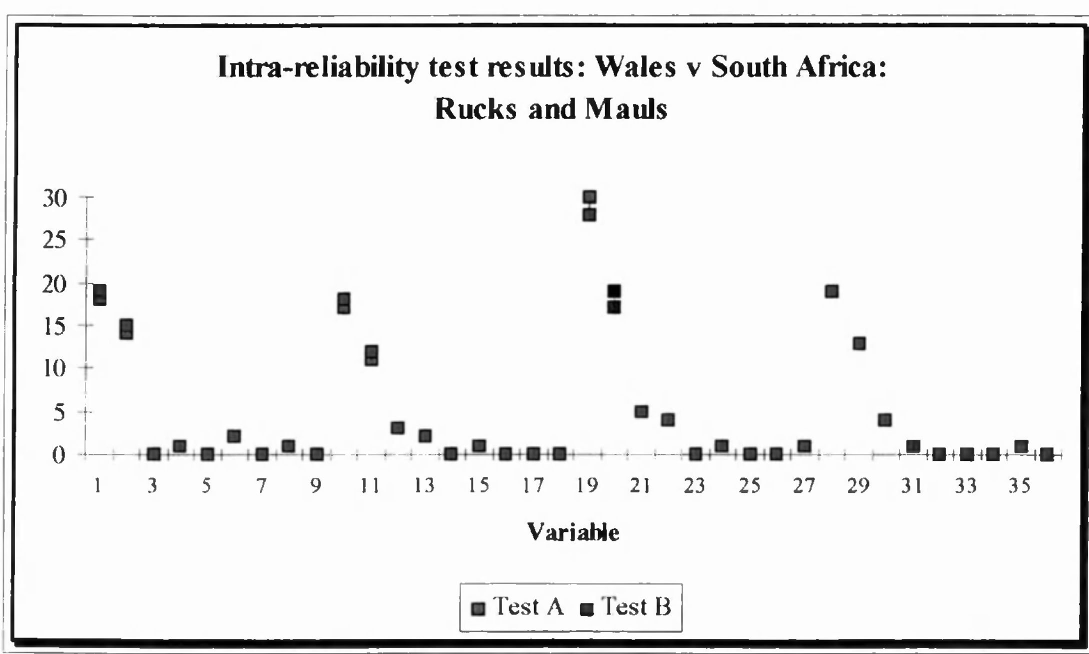

Figure B21: Plots of intra-reliability test for computer notation: Wales v S Africa

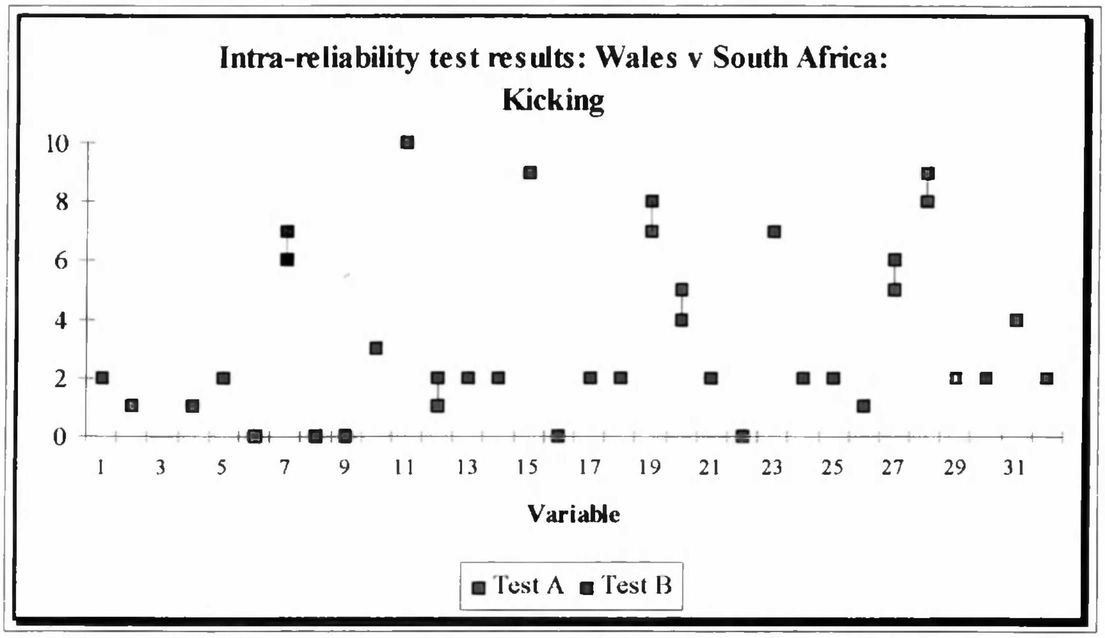

Figure B22: Plots of intra-reliability test for computer notation: Wales v S Africa

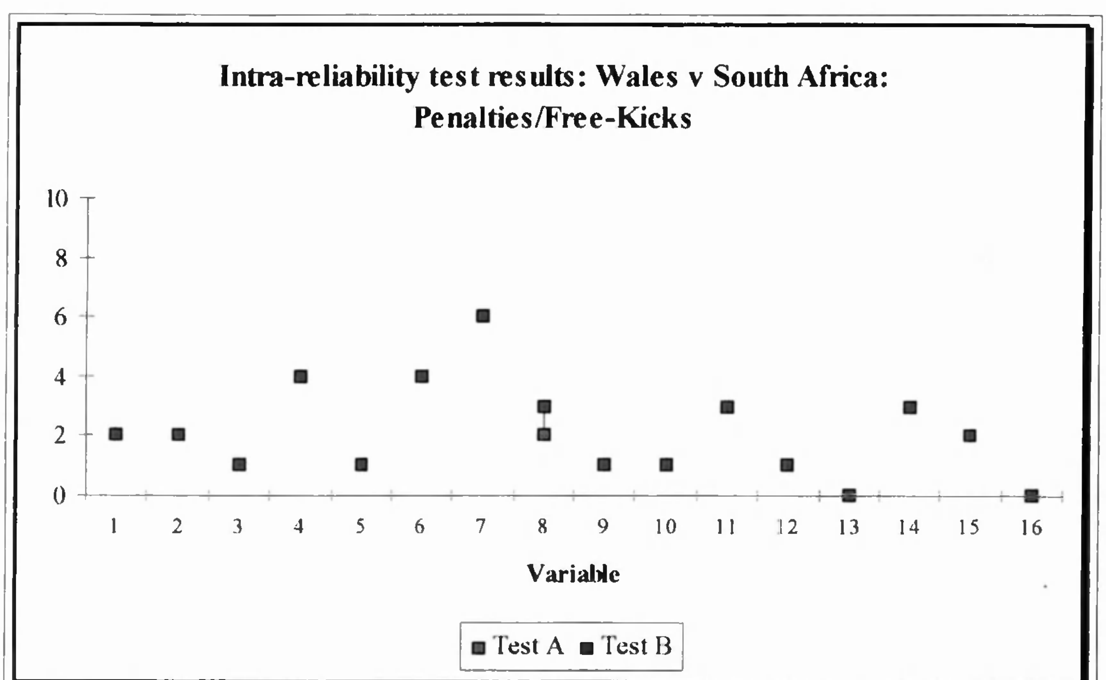

Figure B23: Plots of intra-reliability test for computer notation: Wales v S Africa

Table B9: Inter-reliability test of the hand-notation system: Denmark v Germany

No	Variable	A	B	No	Variable	A	B
1	Denmark Free-kicks conceded (1st Half)	13	13	27	Germany Off-sides (1st half)	3	3
2	Denmark Fouls (1st half)	12	12	28	Germany Hand-balls (1st half)	0	1
3	Denmark Off-sides (1st half)	1	1	29	Germany Throws (2nd Half)	12	11
4	Denmark Hand-balls (1st half)	0	0	30	Germany Corners (2nd Half)	5	5
5	Denmark Throws (1st Half)	8	8	31	Germany Injuries (2nd Half)	0	0
6	Denmark Corners (1st Half)	3	2	32	Germany Goal-kicks (2nd Half)	2	2
7	Denmark Injuries (1st Half)	1	1	33	Denmark GK Long (1st half)	18	16
8	Denmark Goal-kicks (1st Half)	2	2	34	Denmark GK Short (1st half)	8	6
9	Germany Free-kicks conceded (1st Half)	11	10	35	Germany GK Long (1st half)	2	2
10	Germany Fouls (1st half)	7	6	36	Germany GK Short (1st half)	6	5
11	Germany Off-sides (1st half)	4	4	37	Denmark GK Long (1st half)	10	9
12	Germany Hand-balls (1st half)	0	0	38	Denmark GK Short (1st half)	2	3
13	Germany Throws (1st Half)	8	8	39	Germany GK Long (1st half)	2	5
14	Germany Corners (1st Half)	5	5	40	Germany GK Short (1st half)	8	5
15	Germany Injuries (1st Half)	1	1	41	Denmark Shots On target (1st half)	0	0
16	Germany Goal-kicks (1st Half)	3	3	42	Denmark Shots Off target (1st half)	3	3
17	Denmark Free-kicks conceded (2nd Half)	13	13	43	Denmark Goals (1st half)	1	1
18	Denmark Fouls (2nd half)	11	11	44	Germany Shots On target (1st half)	6	5
19	Denmark Off-sides (2nd half)	2	2	45	Germany Shots Off target (1st half)	1	2
20	Denmark Hand-balls (2nd half)	0	0	46	Germany Goals (1st half)	0	0
21	Denmark Throws (2nd Half)	4	3	47	Denmark Shots On target (2nd half)	0	0
22	Denmark Corners (2nd Half)	1	1	48	Denmark Shots Off target (2nd half)	3	3
23	Denmark Injuries (2nd Half)	4	3	49	Denmark Goals (2nd half)	1	1
24	Denmark Goal-kicks (2nd Half)	5	5	50	Germany Shots On target (2nd half)	1	1
25	Germany Free-kicks conceded (2nd Half)	15	15	51	Germany Shots Off target (2ndhalf)	7	5
26	Germany Fouls (1st half)	12	11	52	Germany Goals (2nd half)	0	0

No	Variable	A	B	No	Variable	A	B
1	Denmark Passes (1st Half)	117	110	3	Denmark Passes (2nd Half)	69	68
2	Germany Passes (1st Half)	159	152	4	Germany Passes (2nd Half)	177	175

1. Using Scott's Pi Coefficient of Reliability

pi = Po - Pe / 100 - Pe   where: Po is the proportion of interobserver agreement, Pe is the proportion of agreement that is expected by chance, Pe is determined by squaring the percent of tallies in each category and summing these over the category

pi = (101.12687 - 6.2827262) - 13.222338 / 100 - 13.222338
pi = 81.621806 / 86.777662
pi = **0.9406**

2. Using Agreements/Disagreements

Number of Agreements / Number of Agreements + Number of Disagreements * 100
Number of Agreements: 734 Number of Disagreements 42

= 734/(734+ 42) * 100
= 734/776 * 100
= **94.5876**

Table B10: Scott's Pi Coefficient for hand notation system: Denmark v Germany.

Category A	Category B	A as % of SUM	B as % of SUM	% difference	(mean %) sq
13	13	1.6905072	1.759134	0.0686268	0.0297501
12	12	1.5604681	1.623816	0.0633478	0.0253492
1	1	0.130039	0.135318	0.005279	0.000176
0	0	0	0	0	0
8	8	1.0403121	1.082544	0.0422319	0.0112663
3	2	0.390117	0.270636	0.119481	0.0010915
1	1	0.130039	0.135318	0.005279	0.000176
2	2	0.260078	0.270636	0.010558	0.0007041
11	10	1.4304291	1.35318	0.0772492	0.0193712
7	6	0.9102731	0.811908	0.0983651	0.0074148
4	4	0.520156	0.541272	0.0211159	0.0028166
0	0	0	0	0	0
8	8	1.0403121	1.082544	0.0422319	0.0112663
5	5	0.6501951	0.67659	0.0263949	0.0044009
1	1	0.130039	0.135318	0.005279	0.000176
3	3	0.390117	0.405954	0.015837	0.0015843
13	13	1.6905072	1.759134	0.0686268	0.0297501
11	11	1.4304291	1.488498	0.0580688	0.0213003
2	2	0.260078	0.270636	0.010558	0.0007041
0	0	0	0	0	0
4	3	0.520156	0.405954	0.1142021	0.0021442
1	1	0.130039	0.135318	-0.005279	0.000176
4	3	0.520156	0.405954	0.1142021	0.0021442
5	5	0.6501951	0.67659	0.0263949	0.0044009
15	15	1.9505852	2.02977	0.0791848	0.0396081
12	11	1.5604681	1.488498	0.0719702	0.0232405
3	3	0.390117	0.405954	0.015837	0.0015843
0	1	0	0.135318	0.135318	4.578E-05
12	11	1.5604681	1.488498	0.0719702	0.0232405
5	5	0.6501951	0.67659	0.0263949	0.0044009
0	0	0	0	0	0
2	2	0.260078	0.270636	0.010558	0.0007041
18	16	2.3407022	2.165088	0.1756143	0.0507554
8	6	1.0403121	0.811908	0.2284041	0.0085768
2	2	0.260078	0.270636	0.010558	0.0007041
6	5	0.7802341	0.67659	0.1036441	0.0053058
10	9	0.00013	0.0001218	8.253E-06	1.585E-10
2	3	0.260078	0.405954	0.145876	0.001109
2	5	0.260078	0.67659	0.416512	0.0021934
8	5	1.0403121	0.67659	0.3637221	0.0073694
0	0	0	0	0	0
3	3	0.390117	0.405954	0.015837	0.0015843
1	1	0.130039	0.135318	0.005279	0.000176
6	5	0.7802341	0.67659	0.1036441	0.0053058
1	2	1.7241379	3.4482759	1.7241379	0.0668847
0	0	0	0	0	0
0	0	0	0	0	0
3	3	0.390117	0.405954	0.015837	0.0015843
1	1	0.130039	0.135318	0.005279	0.000176
1	1	0.130039	0.135318	0.005279	0.000176
7	5	0.9102731	0.67659	0.2336831	0.0062953
0	0	0	0	0	0
117	110	15.214564	14.88498	0.3295847	2.2649564
159	152	20.676203	20.568336	0.1078673	4.2527799
69	68	8.9726918	9.2016238	0.228932	0.8257644
177	175	23.016905	23.68065	0.6637445	5.451654
769	**739**	**100.29384**	**101.9599**	**6.2827262**	**13.222338**

3. Using Simple Plots

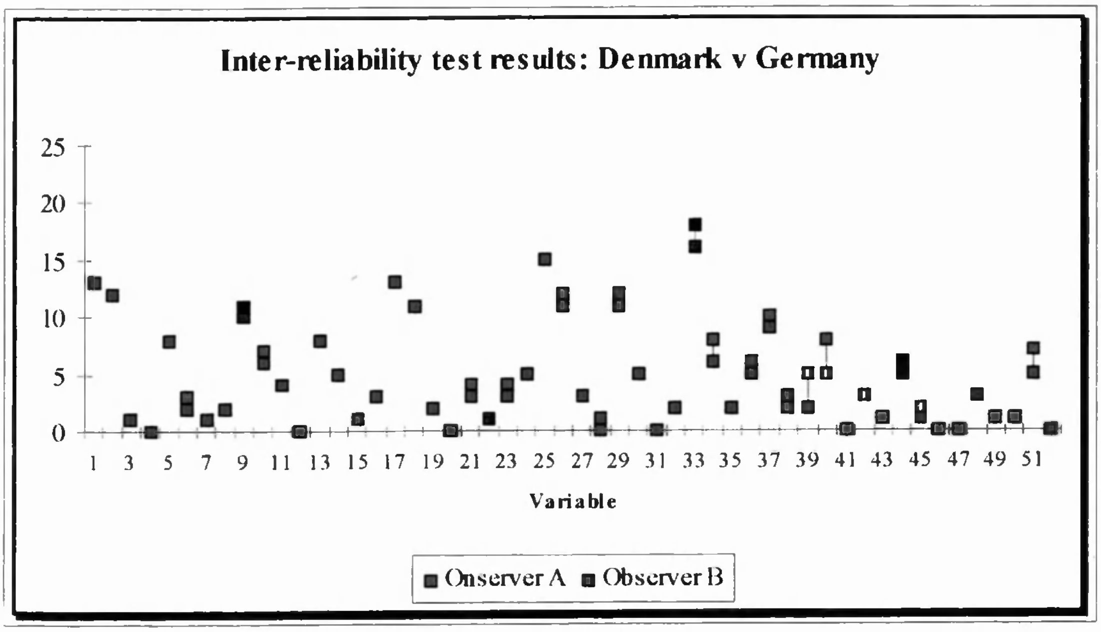

Figure B24: Plots of inter-reliability test for hand notation: Denmark v Germany

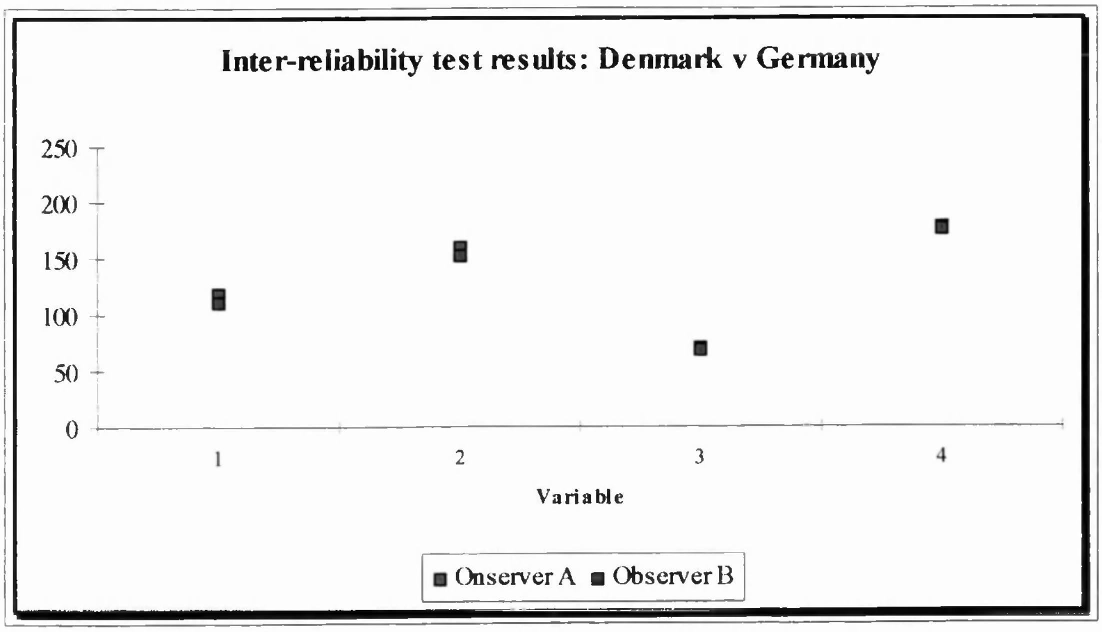

Figure B25: Plots of intra-reliability test for computer notation: Wales v S Africa

Table B11 (a): Inter-reliability test of the hand-notation system: Denmark v Germany

	Variable	A	B
1	Match Time (1st half)	46:13	46:13
2	Match Time (2nd half)	46:09	46:10
3	Ball in Play Time (1st half)	29:44	29:59
4	Ball in Play Time (2nd half)	25:43	25:58
5	Denmark Territorial Time (1st half)	19:20	19:47
6	Denmark Territorial Time (2nd half)	16:04	15:44
7	Germany Territorial Time (1st half)	26:53	26:26
8	Germany Territorial Time (2nd half)	30:05	30:26
9	Denmark Possession Time (1st half)	15:14	15:30
10	Denmark Possession Time (2nd half)	09:51	09:59
11	Germany Possession Time (1st half)	14:25	14:25
12	Germany Possession Time (2nd half)	15:42	15:55
13	Activity Cycles (1st half)	56	59
14	Activity Cycles (2nd half)	58	60
	Variable	**A**	**B**
1	Denmark in Opp Pen Area (1st half)	12	12
2	Denmark in Opp Pen Area (2nd half)	12	13
3	Germany in Opp Pen Area (1st half)	27	25
4	Germany in Opp Pen Area (2nd half)	41	41
5	Denmark Goals (1st half)	1	1
6	Denmark Goals (2nd half)	1	1
7	Germany Goals (1st half)	0	0
8	Germany Goals (2nd half)	0	0
	Variable	**A**	**B**
1	Denmark Throw-Ins (1st half)	8	8
2	Denmark Throw-Ins Retained (1st half)	5	5
3	Denmark Throw-Ins Lost (1st half)	3	3
4	Denmark Throw-Ins Free-kick for (1st half)	0	0
5	Denmark Throw-Ins Free-kick against (1st half)	0	0
6	Denmark Throw-Ins Foul Throw (1st half)	0	0
7	Denmark Throw-Ins Indeterminate (1st half)	0	0
8	Denmark Throw-Ins (2nd half)	5	5
9	Denmark Throw-Ins Retained (2nd half)	3	2
10	Denmark Throw-Ins Lost (2nd half)	1	2
11	Denmark Throw-Ins Free-kick for (2nd half)	1	1
12	Denmark Throw-Ins Free-kick against (2nd half)	0	0
13	Denmark Throw-Ins Foul Throw (2nd half)	0	0
14	Denmark Throw-Ins Indeterminate (2nd half)	0	0
15	Germany Throw-Ins (1st half)	8	8

Table B11 (b): Inter-reliability test of the hand-notation system: Denmark v Germany

	Variable	A	B
16	Germany Throw-Ins Retained (1st half)	8	8
17	Germany Throw-Ins Lost (1st half)	0	0
18	Germany Throw-Ins Free-kick for (1st half)	0	0
19	Germany Throw-Ins Free-kick against (1st half)	0	0
20	Germany Throw-Ins Foul Throw (1st half)	0	0
21	Germany Throw-Ins Indeterminate (1st half)	0	0
22	Germany Throw-Ins (2nd half)	13	12
23	Germany Throw-Ins Retained (2nd half)	12	11
24	Germany Throw-Ins Lost (2nd half)	1	1
25	Germany Throw-Ins Free-kick for (2nd half)	0	0
26	Germany Throw-Ins Free-kick against (2nd half)	0	0
27	Germany Throw-Ins Foul Throw (2nd half)	0	0
28	Germany Throw-Ins Indeterminate (2nd half)	0	0
	Variable	**A**	**B**
1	Denmark Goal-keeper Possessions For (1st half)	31	29
2	Denmark Goal-keeper Possessions Retained (1st half)	19	18
3	Denmark Goal-keeper Possessions Lost (1st half)	11	10
4	Denmark Goal-keeper Possessions Free-kick For (1st half)	0	0
5	Denmark Goal-keeper Possessions Free-kick Against (1st half)	1	1
6	Denmark Goal-keeper Possessions Indeterminate (1st half)	0	0
7	Denmark Goal-keeper Possessions For (2nd half)	17	16
8	Denmark Goal-keeper Possessions Retained (2nd half)	3	3
9	Denmark Goal-keeper Possessions Lost (2nd half)	13	12
10	Denmark Goal-keeper Possessions Free-kick For (2nd half)	1	1
11	Denmark Goal-keeper Possessions Free-kick Against (2nd half)	0	0
12	Denmark Goal-keeper Possessions Indeterminate (2nd half)	0	0
13	Germany Goal-keeper Possessions For (1st half)	11	11
14	Germany Goal-keeper Possessions Retained (1st half)	9	9
15	Germany Goal-keeper Possessions Lost (1st half)	1	1
16	Germany Goal-keeper Possessions Free-kick For (1st half)	0	0
17	Germany Goal-keeper Possessions Free-kick Against (1st half)	1	1
18	Germany Goal-keeper Possessions Indeterminate (1st half)	0	0
19	Germany Goal-keeper Possessions For (2nd half)	11	11
20	Germany Goal-keeper Possessions Retained (2nd half)	9	10
21	Germany Goal-keeper Possessions Lost (2nd half)	2	1
22	Germany Goal-keeper Possessions Free-kick For (2nd half)	0	0
23	Germany Goal-keeper Possessions Free-kick Against (2nd half)	0	0
24	Germany Goal-keeper Possessions Indeterminate (2nd half)	0	0

Table B11 (c): Inter-reliability test of the hand-notation system: Denmark v Germany

	Variable	A	B
1	Denmark Passes Attempted (1st half)	159	149
2	Denmark Passes Retained (1st half)	117	112
3	Denmark Passes Lost (1st half)	42	37
4	Denmark Passes Attempted (2nd half)	105	103
5	Denmark Passes Retained (2nd half)	77	75
6	Denmark Passes Lost (2nd half)	28	28
7	Germany Passes Attempted (1st half)	219	219
8	Germany Passes Retained (1st half)	168	166
9	Germany Passes Lost (1st half)	51	53
10	Germany Passes Attempted (2nd half)	231	227
11	Germany Passes Retained (2nd half)	190	187
12	Germany Passes Lost (2nd half)	41	40
	Variable	**A**	**B**
1	Denmark Free-kicks/Penalties Conceded in Own PA (1st half)	0	0
2	Denmark Free-kicks/Penalties Conceded in Own Half (1st half)	6	6
3	Denmark Free-kicks/Penalties Conceded in Opp Half (1st half)	7	6
4	Denmark Free-kicks/Penalties Conceded in Own PA (2nd half)	0	0
5	Denmark Free-kicks/Penalties Conceded in Own Half (2nd half)	7	7
6	Denmark Free-kicks/Penalties Conceded in Opp Half (2nd half)	6	6
7	Germany Free-kicks/Penalties Conceded in Own PA (1st half)	0	0
8	Germany Free-kicks/Penalties Conceded in Own Half (1st half)	1	1
9	Germany Free-kicks/Penalties Conceded in Opp Half (1st half)	10	9
10	Germany Free-kicks/Penalties Conceded in Own PA (2nd half)	0	0
11	Germany Free-kicks/Penalties Conceded in Own Half (2nd half)	6	5
12	Germany Free-kicks/Penalties Conceded in Opp Half (2nd half)	8	8
	Variable	**A**	**B**
1	Denmark Shots Successful (1st half)	1	1
2	Denmark Shots Unsuccessful (1st half)	2	2
3	Denmark Headers Successful (1st half)	0	0
4	Denmark Headers Unsuccessful (1st half)	0	0
5	Denmark Shots Successful (2nd half)	1	1
6	Denmark Shots Unsuccessful (2nd half)	3	3
7	Denmark Headers Successful (2nd half)	0	0
8	Denmark Headers Unsuccessful (2nd half)	0	0
9	Germany Shots Successful (1st half)	6	5
10	Germany Shots Unsuccessful (1st half)	1	2
11	Germany Headers Successful (1st half)	0	0
12	Germany Headers Unsuccessful (1st half)	1	1
13	Germany Shots Successful (2nd half)	1	0
14	Germany Shots Unsuccessful (2nd half)	4	4
15	Germany Headers Successful (2nd half)	1	1
16	Germany Headers Unsuccessful (2nd half)	1	1

Table B11 (d): Inter-reliability test of the hand-notation system: Denmark v Germany

No	Variable	A	B
1	Denmark Crosses Successful (1st half)	0	0
2	Denmark Crosses Unsuccessful (1st half)	3	4
3	Denmark Corners Successful (1st half)	1	1
4	Denmark Corners Unsuccessful (1st half)	2	3
5	Denmark Crosses Successful (2nd half)	0	0
6	Denmark Crosses Unsuccessful (2nd half)	5	5
7	Denmark Corners Successful (2nd half)	0	0
8	Denmark Corners Unsuccessful (2nd half)	1	1
9	Germany Crosses Successful (1st half)	2	2
10	Germany Crosses Unsuccessful (1st half)	10	10
11	Germany Corners Successful (1st half)	2	1
12	Germany Corners Unsuccessful (1st half)	3	4
13	Germany Crosses Successful (2nd half)	9	10
14	Germany Crosses Unsuccessful (2nd half)	13	12
15	Germany Corners Successful (2nd half)	0	0
16	Germany Corners Unsuccessful (2nd half)	5	5

1. Using Scott's Pi Coefficient of Reliability

pi = Po - Pe / 100 - Pe

where: Po is the proportion of interobserver agreement
Pe is the proportion of agreement that is expected by chance
Pe is determined by squaring the percent of tallies in each category and summing these all over the category

pi = (100.27289 - 2.9753151) - 6.8554229 / 100 - 6.8554229
pi = 97.297575 - 6.8554229 / 93.144577
pi = 90.442152 / 93.144577
pi = **0.9709867**

2. Using Agreements/Disagreements

Number of Agreements / Number of Agreements + Number of Disagreements * 100
Number of Agreements: 1806 Number of Disagreements 63

= 1806/(1806+ 63) * 100
= 1806/1869* 100
= 0.96629213 * 100
= **96.6292**

Table B12: Scott's Pi Coefficient for computer system: Denmark v Germany.

Category A	Category B	A as % of SUM	B as % of SUM	% difference	(mean %) sq
12	12	0.6472492	0.6626173	0.0153681	0.0042894
12	13	0.6472492	0.7178355	0.0705863	0.0046586
27	25	1.4563107	1.3804528	0.0758579	0.0201181
41	41	2.2114347	2.2639426	0.0525078	0.0500725
1	1	0.0539374	0.0552181	0.0012807	2.979E-05
1	1	0.0539374	0.0552181	0.0012807	2.979E-05
0	0	0	0	0	0
0	0	0	0	0	0
8	8	0.4314995	0.4417449	0.0102454	0.0019064
5	5	0.2696872	0.2760906	0.0064034	0.0007447
3	3	0.1618123	0.1656543	0.003842	0.0002681
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
5	5	0.2696872	0.2760906	0.0064034	0.0007447
3	2	0.1618123	0.1104362	0.0513761	0.0001853
1	2	0.0539374	0.1104362	0.0564988	6.755E-05
1	1	0.0539374	0.0552181	0.0012807	2.979E-05
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
8	8	0.4314995	0.4417449	0.0102454	0.0019064
8	8	0.4314995	0.4417449	0.0102454	0.0019064
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
13	12	0.7011866	0.6626173	0.0385693	0.0046499
12	11	0.6472492	0.6073992	0.03985	0.0039354
1	1	0.0539374	0.0552181	0.0012807	2.979E-05
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
31	29	1.6720604	1.6013252	0.0707352	0.0267876
19	18	1.0248112	0.993926	0.0308852	0.0101882
11	10	0.5933118	0.5521811	0.0411306	0.0032804
0	0	0	0	0	0
1	1	0.0539374	0.0552181	-0.0012807	2.979E-05
0	0	0	0	0	0
17	16	0.9169364	0.8834898	0.0334466	0.0081038
3	3	0.1618123	0.1656543	-0.003842	0.0002681
13	12	0.7011866	0.6626173	0.0385693	0.0046499
1	1	0.0539374	0.0552181	0.0012807	2.979E-05
0	0	0	0	0	0
0	0	0	0	0	0
11	11	0.5933118	0.6073992	0.0140875	0.0036043
9	9	0.4854369	0.496963	0.0115261	0.0024128
1	1	0.0539374	0.0552181	0.0012807	2.979E-05
0	0	0	0	0	0
1	1	0.0539374	0.0552181	0.0012807	2.979E-05
0	0	0	0	0	0
11	11	0.5933118	0.6073992	0.0140875	0.0036043
9	10	0.4854369	0.5521811	0.0667442	0.0026916
2	1	0.1078749	0.0552181	0.0526568	6.65E-05
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
159	149	8.5760518	8.2274986	0.3485532	0.7058983
117	112	6.3106796	6.1844285	0.1262511	0.3903193
42	37	2.2653722	2.0430701	0.222302	0.0464067
105	103	5.6634304	5.6874655	-0.0240351	0.3221071

77	75	4.1531823	4.1413584	0.0118239	0.1719985
28	28	1.5102481	1.5461071	0.035859	0.0233533
219	219	11.812298	12.092766	0.2804687	1.4286302
168	166	9.0614887	9.1662065	0.1047178	0.8306222
51	53	2.7508091	2.9265599	0.1757509	0.0805813
231	227	12.459547	12.534511	0.0749644	1.5617574
190	187	10.248112	10.325787	0.0776747	1.0582133
41	40	2.2114347	2.2087245	0.0027103	0.0488445
0	0	0	0	0	0
6	6	0.3236246	0.3313087	0.0076841	0.0010723
7	6	0.377562	0.3313087	0.0462534	0.0012562
0	0	0	0	0	0
7	7	0.377562	0.3865268	0.0089648	0.0014596
6	6	0.3236246	0.3313087	0.0076841	0.0010723
0	0	0	0	0	0
1	1	0.0539374	0.0552181	0.0012807	2.979E-05
10	9	0.5393743	0.496963	0.0424113	0.002685
0	0	0	0	0	0
6	5	0.3236246	0.2760906	0.047534	0.0008991
8	8	0.4314995	0.4417449	0.0102454	0.0019064
1	1	0.0539374	0.0552181	0.0012807	2.979E-05
2	2	0.1078749	0.1104362	0.0025614	0.0001191
0	0	0	0	0	0
0	0	0	0	0	0
1	1	0.0539374	0.0552181	0.0012807	2.979E-05
3	3	0.1618123	0.1656543	0.003842	0.0002681
0	0	0	0	0	0
0	0	0	0	0	0
6	5	0.3236246	0.2760906	0.047534	0.0008991
1	2	0.0539374	0.1104362	0.0564988	6.755E-05
0	0	0	0	0	0
1	1	0.0539374	0.0552181	0.0012807	2.979E-05
1	0	0.0539374	0	0.0539374	7.273E-06
4	4	0.2157497	0.2208724	0.0051227	0.0004766
1	1	0.0539374	0.0552181	0.0012807	2.979E-05
1	1	0.0539374	0.0552181	0.0012807	2.979E-05
0	0	0	0	0	0
3	4	0.1618123	0.2208724	0.0590601	0.0003661
1	1	0.0539374	0.0552181	0.0012807	2.979E-05
2	3	0.1078749	0.1656543	0.0577795	0.000187
0	0	0	0	0	0
5	5	0.2696872	0.2760906	0.0064034	0.0007447
0	0	0	0	0	0
1	1	0.0539374	0.0552181	0.0012807	2.979E-05
2	2	0.1078749	0.1104362	0.0025614	0.0001191
10	10	0.5393743	0.5521811	0.0128068	0.0029787
2	1	0.1078749	0.0552181	0.0526568	6.65E-05
3	4	0.1618123	0.2208724	0.0590601	0.0003661
9	10	0.4854369	0.5521811	0.0667442	0.0026916
13	12	0.7011866	0.6626173	0.0385693	0.0046499
0	0	0	0	0	0
5	5	0.2696872	0.2760906	0.0064034	0.0007447
1854	**1811**	**100.26969**	**100.27609**	**2.9753151**	**6.8554229**

3. Using Simple Plots

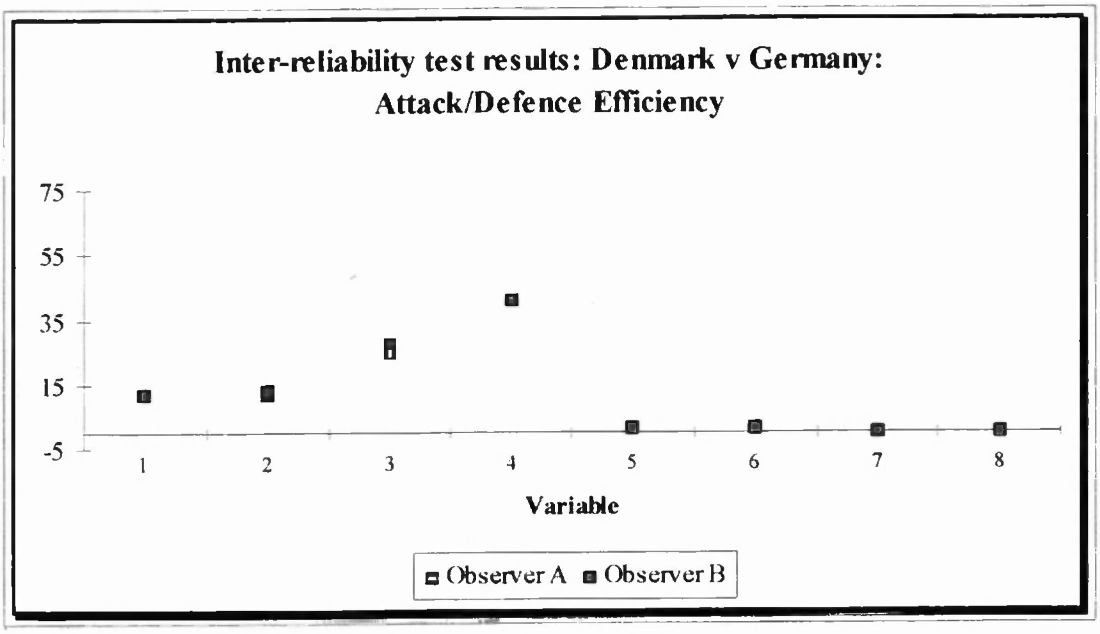

Figure B26: Plots of inter-reliability test for computer notation: Denmark v Germany

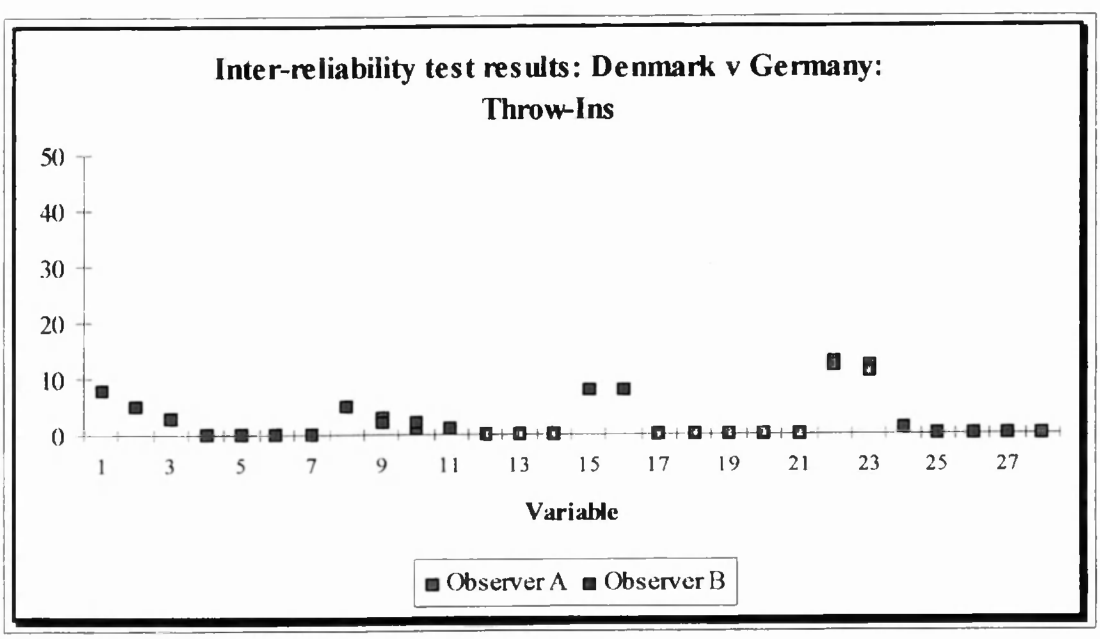

Figure B27: Plots of inter-reliability test for computer notation: Denmark v Germany

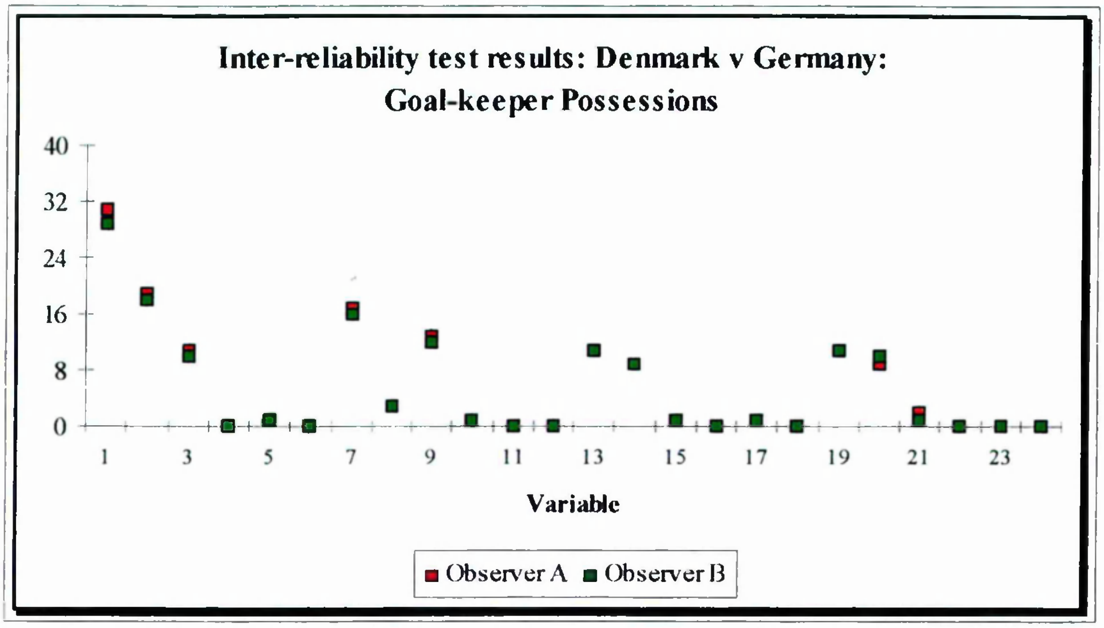

Figure B28: Plots of inter-reliability test for computer notation: Denmark v Germany

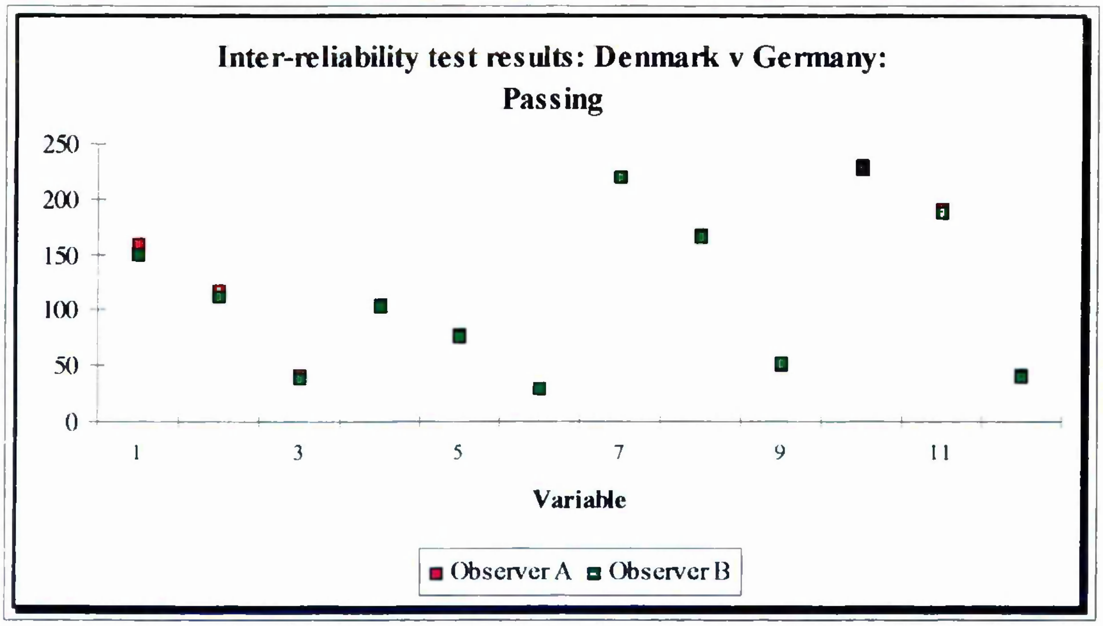

Figure B29: Plots of inter-reliability test for computer notation: Denmark v Germany

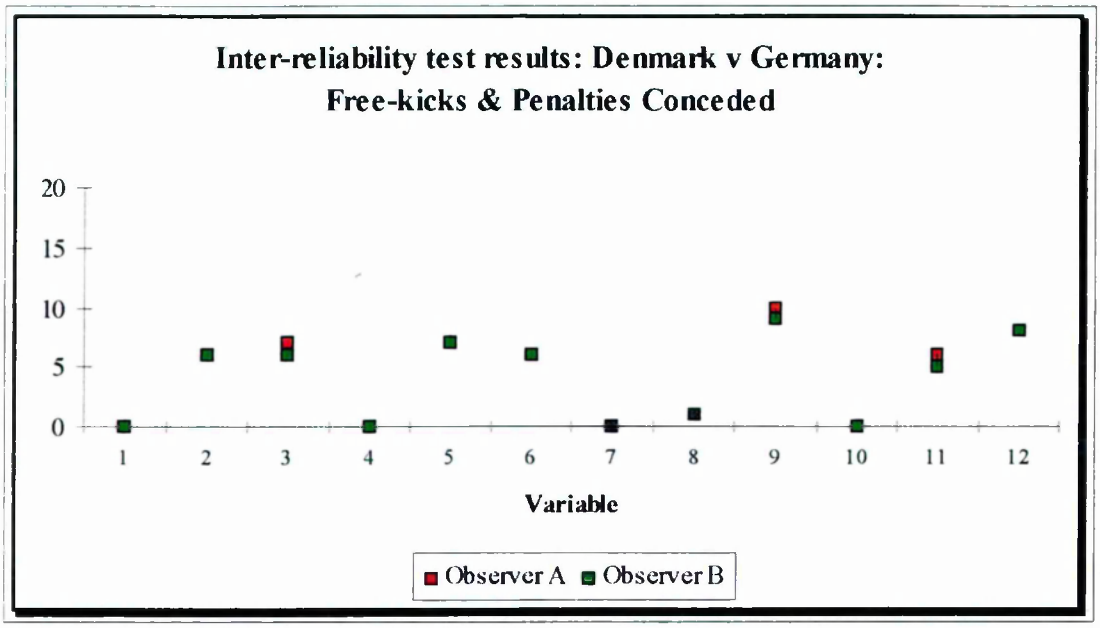

Figure B30: Plots of inter-reliability test for computer notation: Denmark v Germany

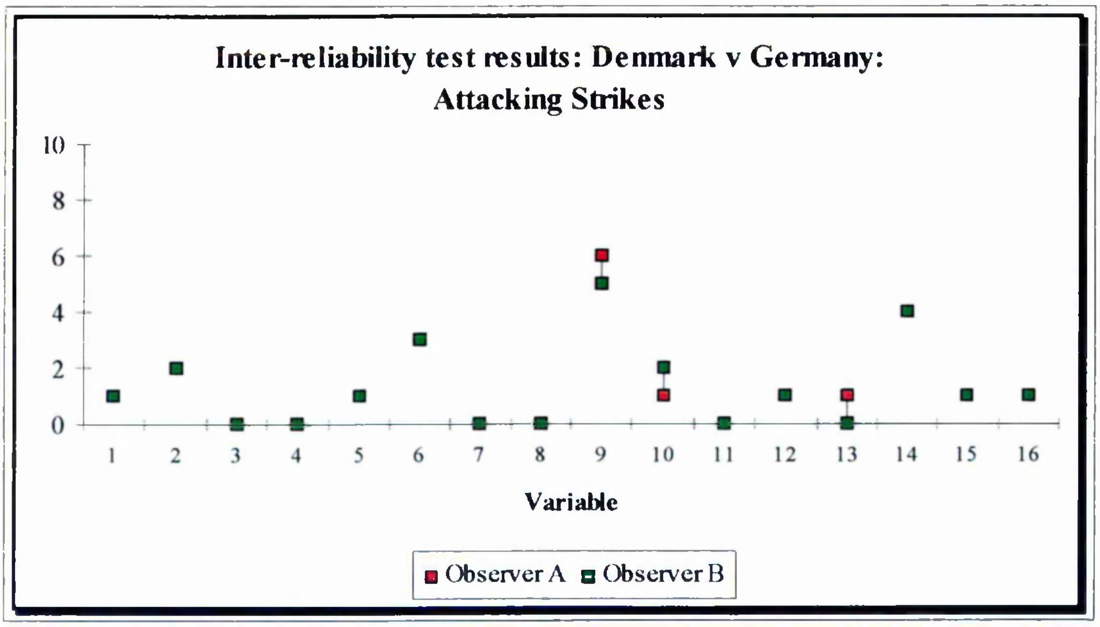

Figure B31: Plots of inter-reliability test for computer notation: Denmark v Germany

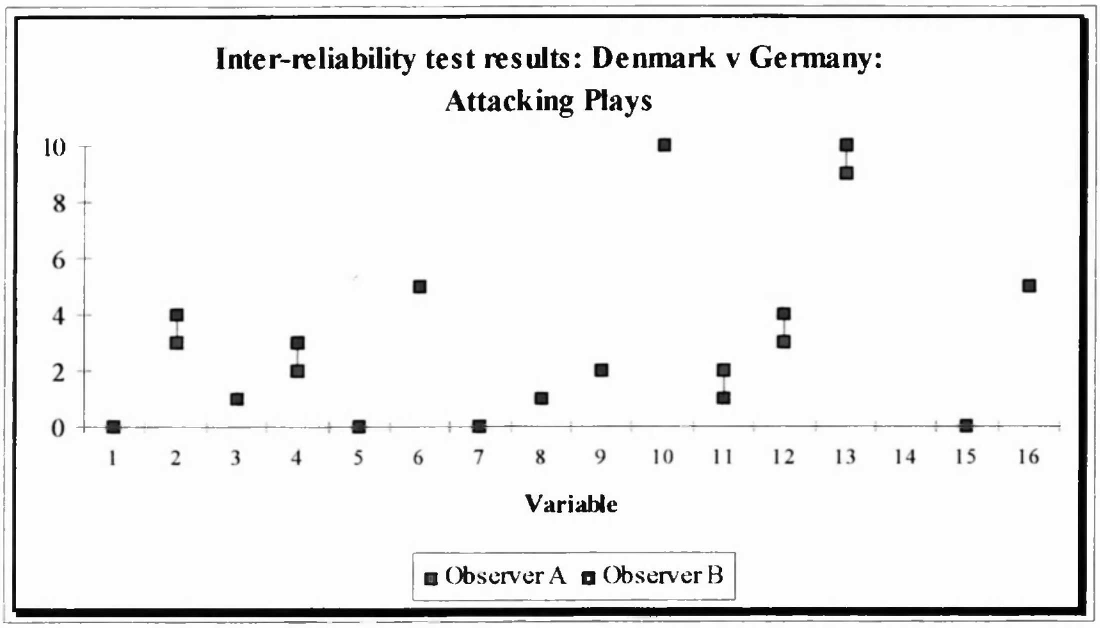

Figure B32: Plots of inter-reliability test for computer notation: Denmark v Germany

Table B13 (a): Inter-reliability test of the computer-notation system: Wales v S Africa

	Variable	A	B
1	Match Time (1st half)	42:39	42:40
2	Match Time (2nd half)	41:11	41:11
3	Ball in Play Time (1st half)	12:23	12:45
4	Ball in Play Time (2nd half)	13:19	13:34
5	Wales Territorial Time (1st half)	23:06	23:00
6	Wales Territorial Time (2nd half)	19:52	20:30
7	S Africa Territorial Time (1st half)	19:33	19:40
8	S Africa Territorial Time (2nd half)	21:19	20:41
9	Wales Possession Time (1st half)	05:00	05:24
10	Wales Possession Time (2nd half)	04:07	04:12
11	S Africa Possession Time (1st half)	06:22	06:36
12	S Africa Possession Time (2nd half)	04:27	04:50
13	Activity Cycles (1st half)	67	67
14	Activity Cycles (2nd half)	51	52
	Variable	**A**	**B**
1	Wales in Opp 22m Area (1st half)	9	9
2	Wales in Opp 22m Area (2nd half)	1	1
3	S Africa in Opp 22m Area (1st half)	3	4
4	S Africa in Opp 22m Area (2nd half)	3	3
5	Wales Tries (1st half)	0	0
6	Wales Tries (2nd half)	0	0
7	S Africa Tries (1st half)	2	2
8	S Africa Tries (2nd half)	1	1
	Variable	**A**	**B**
1	Wales Line-Outs (1st half)	12	12
2	Wales Line-Outs Won (1st half)	10	10
3	Wales Line-Outs Lost (1st half)	1	1
4	Wales Line-Outs Penalty for (1st half)	1	1
5	Wales Line-Outs Free-kick for (1st half)	0	0
6	Wales Line-Outs Penalty against (1st half)	0	0
7	Wales Line-Outs Free-kick against (1st half)	0	0
8	Wales Line-Outs Not straight/Not 5m (1st half)	0	0
9	Wales Line-Outs Knock-ons (1st half)	0	0
10	S Africa Line-Outs (1st half)	16	16
11	S Africa Line-Outs Won (1st half)	8	8
12	S Africa Line-Outs Lost (1st half)	3	3
13	S Africa Line-Outs Penalty for (1st half)	1	1
14	S Africa Line-Outs Free-kick for (1st half)	1	1
15	S Africa Line-Outs Penalty against (1st half)	1	2

Table B13 (b): Inter-reliability test of the computer-notation system: Wales v S Africa

	Variable	A	B
16	S Africa Line-Outs Free-kick against (1st half)	2	1
17	S Africa Line-Outs Not straight/Not 5m (1st half)	0	0
18	S Africa Line-Outs Knock-ons (1st half)	0	0
19	Wales Line-Outs (2nd half)	10	10
20	Wales Line-Outs Won (2nd half)	10	10
21	Wales Line-Outs Lost (2nd half)	0	0
22	Wales Line-Outs Penalty for (2nd half)	0	0
23	Wales Line-Outs Free-kick for (2nd half)	0	0
24	Wales Line-Outs Penalty against (2nd half)	0	0
25	Wales Line-Outs Free-kick against (2nd half)	0	0
26	Wales Line-Outs Not straight/Not 5m (2nd half)	0	0
27	Wales Line-Outs Knock-ons (2nd half)	0	0
28	S Africa Line-Outs (2nd half)	12	12
29	S Africa Line-Outs Won (2nd half)	9	10
30	S Africa Line-Outs Lost (2nd half)	3	2
31	S Africa Line-Outs Penalty for (2nd half)	0	0
32	S Africa Line-Outs Free-kick for (2nd half)	0	0
33	S Africa Line-Outs Penalty against (2nd half)	0	0
34	S Africa Line-Outs Free-kick against (2nd half)	0	0
35	S Africa Line-Outs Not straight/Not 5m (2nd half)	0	0
36	S Africa Line-Outs Knock-ons (2nd half)	0	0

	Variable	A	B
1	Wales Scrums (1st half)	8	8
2	Wales Scrums Won (1st half)	5	5
3	Wales Scrums Lost (1st half)	1	1
4	Wales Scrums Penalty for (1st half)	0	0
5	Wales Scrums Free-kick for (1st half)	0	0
6	Wales Scrums Penalty against (1st half)	0	0
7	Wales Scrums Free-kick against (1st half)	0	0
8	Wales Scrums Collapsed/Disengaged (1st half)	0	1
9	Wales Scrums Wheeled 90 (1st half)	2	1
10	S Africa Scrums (1st half)	7	7
11	S Africa Scrums Won (1st half)	3	3
12	S Africa Scrums Lost (1st half)	0	0
13	S Africa Scrums Penalty for (1st half)	0	0
14	S Africa Scrums Free-kick for (1st half)	0	0
15	S Africa Scrums Penalty against (1st half)	0	0
16	S Africa Scrums Free-kick against (1st half)	1	1
17	S Africa Scrums Collapsed/Disengaged (1st half)	2	2
18	S Africa Scrums Wheeled 90 (1st half)	1	1
19	Wales Scrums (2nd half)	3	3
20	Wales Scrums Won (2nd half)	3	3
21	Wales Scrums Lost (2nd half)	0	0

Table B13 (c): Inter-reliability test of the computer-notation system: Wales v S Africa

	Variable	A	B
22	Wales Scrums Penalty for (2nd half)	0	0
23	Wales Scrums Free-kick for (2nd half)	0	0
24	Wales Scrums Penalty against (2nd half)	0	0
25	Wales Scrums Free-kick against (2nd half)	0	0
26	Wales Scrums Collapsed/Disengaged (2nd half)	0	0
27	Wales Scrums Wheeled 90 (2nd half)	0	0
28	S Africa Scrums (2nd half)	6	6
29	S Africa Scrums Won (2nd half)	5	5
30	S Africa Scrums Lost (2nd half)	0	0
31	S Africa Scrums Penalty for (2nd half)	0	0
32	S Africa Scrums Free-kick for (2nd half)	0	0
33	S Africa Scrums Penalty against (2nd half)	0	1
34	S Africa Scrums Free-kick against (2nd half)	1	0
35	S Africa Scrums Collapsed/Disengaged (2nd half)	0	0
36	S Africa Scrums Wheeled 90 (2nd half)	0	0
	Variable	**A**	**B**
1	Wales Rucks/Mauls (1st half)	18	17
2	Wales Rucks/Mauls Won (1st half)	14	13
3	Wales Rucks/Mauls Lost (1st half)	0	0
4	Wales Rucks/Mauls Penalty for (1st half)	1	1
5	Wales Rucks/Mauls Free-kick for (1st half)	0	0
6	Wales Rucks/Mauls Penalty against (1st half)	2	2
7	Wales Rucks/Mauls Free-kick against (1st half)	0	0
8	Wales Rucks/Mauls Own Scrum (1st half)	1	1
9	Wales Rucks/Mauls Opp Scrum (1st half)	0	0
10	S Africa Rucks/Mauls (1st half)	17	16
11	S Africa Rucks/Mauls Won (1st half)	11	10
12	S Africa Rucks/Mauls Lost (1st half)	3	3
13	S Africa Rucks/Mauls Penalty for (1st half)	2	1
14	S Africa Rucks/Mauls Free-kick for (1st half)	0	1
15	S Africa Rucks/Mauls Penalty against (1st half)	1	1
16	S Africa Rucks/Mauls Free-kick against (1st half)	0	0
17	S Africa Rucks/Mauls Own Scrum (1st half)	0	0
18	S Africa Rucks/Mauls Opp Scrum (1st half)	0	0
19	Wales Rucks/Mauls (2nd half)	30	30
20	Wales Rucks/Mauls Won (2nd half)	19	19
21	Wales Rucks/Mauls Lost (2nd half)	5	5
22	Wales Rucks/Mauls Penalty for (2nd half)	4	4
23	Wales Rucks/Mauls Free-kick for (2nd half)	0	0
24	Wales Rucks/Mauls Penalty against (2nd half)	1	1
25	Wales Rucks/Mauls Free-kick against (2nd half)	0	0
26	Wales Rucks/Mauls Own Scrum (2nd half)	0	0
27	Wales Rucks/Mauls Opp Scrum (2nd half)	1	1

Table B13 (d): Inter-reliability test of the computer-notation system: Wales v S Africa

No	Variable	A	B
28	S Africa Rucks/Mauls (2nd half)	19	18
29	S Africa Rucks/Mauls Won (2nd half)	13	12
30	S Africa Rucks/Mauls Lost (2nd half)	4	4
31	S Africa Rucks/Mauls Penalty for (2nd half)	1	1
32	S Africa Rucks/Mauls Free-kick for (2nd half)	0	0
33	S Africa Rucks/Mauls Penalty against (2nd half)	0	0
34	S Africa Rucks/Mauls Free-kick against (2nd half)	0	0
35	S Africa Rucks/Mauls Own Scrum (2nd half)	1	1
36	S Africa Rucks/Mauls Opp Scrum (2nd half)	0	0

No	Variable	A	B
1	Wales Goal-kicks Successful (1st half)	2	2
2	Wales Goal-kicks Unsuccessful (1st half)	1	1
3	Wales Touch Successful (1st half)	12	11
4	Wales Touch Unsuccessful (1st half)	1	1
5	Wales Goal-kicks Successful (2nd half)	2	2
6	Wales Goal-kicks Unsuccessful (2nd half)	0	0
7	Wales Touch Successful (2nd half)	6	6
8	Wales Touch Unsuccessful (2nd half)	0	0
9	S Africa Goal-kicks Successful (1st half)	0	0
10	S Africa Goal-kicks Unsuccessful (1st half)	3	3
11	S Africa Touch Successful (1st half)	10	9
12	S Africa Touch Unsuccessful (1st half)	1	1
13	S Africa Goal-kicks Successful (2nd half)	2	2
14	S Africa Goal-kicks Unsuccessful (2nd half)	2	2
15	S Africa Touch Successful (2nd half)	9	7
16	S Africa Touch Unsuccessful (2nd half)	0	0
17	Wales Restarts Successful (1st half)	2	3
18	Wales Restarts Unsuccessful (1st half)	2	1
19	Wales Other Successful (1st half)	7	5
20	Wales Other Unsuccessful (1st half)	5	5
21	Wales Restarts Successful (2nd half)	2	1
22	Wales Restarts Unsuccessful (2nd half)	0	1
23	Wales Other Successful (2nd half)	7	6
24	Wales Other Unsuccessful (2nd half)	2	2
25	S Africa Restarts Successful (1st half)	2	2
26	S Africa Restarts Unsuccessful (1st half)	1	1
27	S Africa Other Successful (1st half)	5	5
28	S Africa Other Unsuccessful (1st half)	8	5
29	S Africa Restarts Successful (2nd half)	2	2
30	S Africa Restarts Unsuccessful (2nd half)	2	2
31	S Africa Other Successful (2nd half)	4	4
32	S Africa Other Unsuccessful (2nd half)	2	2

Table B13 (e): Inter-reliability test of the computer-notation system: Wales v S Africa

No	Variable	A	B
1	Wales Free-kicks/Penalties Conceded in Own 22m(1st half)	2	2
2	Wales Free-kicks/Penalties Conceded in Own 22m-Half Way (1st half)	2	2
3	Wales Free-kicks/Penalties Conceded in Half Way - Opp 22m (1st half)	1	1
4	Wales Free-kicks/Penalties Conceded in Opp 22m (2nd half)	4	4
5	S Africa Free-kicks/Penalties Conceded in Own 22m (1st half)	1	2
6	S Africa Free-kicks/Penalties Conceded in Own 22m-Half Way (1st half)	4	3
7	S Africa Free-kicks/Penalties Conceded in Half Way - Opp 22m (1st half)	6	5
8	S Africa Free-kicks/Penalties Conceded in Opp 22m (2nd half)	2	2
9	Wales Free-kicks/Penalties Conceded in Own 22m (2nd half)	1	1
10	Wales Free-kicks/Penalties Conceded in Own 22m-Half Way (2nd half)	1	1
11	Wales Free-kicks/Penalties Conceded in Half Way - Opp 22m (2nd half)	3	2
12	Wales Free-kicks/Penalties Conceded in Opp 22m (2nd half)	1	1
13	S Africa Free-kicks/Penalties Conceded in Own 22m (2nd half)	0	0
14	S Africa Free-kicks/Penalties Conceded in Own 22m-Half Way (2nd half)	3	2
15	S Africa Free-kicks/Penalties Conceded in Half Way - Opp 22m (2nd half)	2	3
16	S Africa Free-kicks/Penalties Conceded in Opp 22m (2nd half)	0	0

1. Using Scott's Pi Coefficient of Reliability

pi = Po - Pe / 100 - Pe

where: Po is the proportion of interobserver agreement
Pe is the proportion of agreement that is expected by chance
Pe is determined by squaring the percent of tallies in each category and summing these all over the category

pi = (100.5189 - 9.3493408) - 2.2116909 / 100 - 2.2116909
pi = 88.957868 / 97.788309
pi = **0.9097**

2. Using Agreements/Disagreements calculations

Number of Agreements / Number of Agreements + Number of Disagreements * 100

Number of Agreements: 445 Number of Disagreements 36

= 445/(445+ 36) * 100
= 445/481 * 100
= 0.9251559 * 100
= **92.5156**

Table B14: Scott's Pi Coefficient for computer notation system: Wales v S Africa.

Category A	Category B	A as % of SUM	B as % of SUM	% difference	(mean %) sq
9	9	1.9067797	1.978022	0.0712423	0.0377292
1	1	0.2118644	0.2197802	0.0079158	0.0004658
3	4	0.6355932	0.8791209	0.2435277	0.0057359
3	3	0.6355932	0.6593407	0.0237474	0.0041921
0	0	0	0	0	0
0	0	0	0	0	0
2	2	0.4237288	0.4395604	0.0158316	0.0018632
1	1	0.2118644	0.2197802	0.0079158	0.0004658
12	12	2.5423729	2.6373626	0.0949898	0.0670742
10	10	2.1186441	2.1978022	0.0791581	0.0465793
1	1	0.2118644	0.2197802	0.0079158	0.0004658
1	1	0.2118644	0.2197802	0.0079158	0.0004658
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
16	16	3.3898305	3.5164835	0.126653	0.1192429
8	8	1.6949153	1.7582418	0.0633265	0.0298107
3	3	0.6355932	0.6593407	0.0237474	0.0041921
1	1	0.2118644	0.2197802	0.0079158	0.0004658
1	1	0.2118644	0.2197802	0.0079158	0.0004658
1	2	0.2118644	0.4395604	0.227696	0.0010609
2	1	0.4237288	0.2197802	0.2039486	0.0010353
0	0	0	0	0	0
0	0	0	0	0	0
10	10	2.1186441	2.1978022	0.0791581	0.0465793
10	10	2.1186441	2.1978022	0.0791581	0.0465793
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
12	12	2.5423729	2.6373626	0.0949898	0.0670742
9	10	1.9067797	2.1978022	0.2910225	0.042119
3	2	0.6355932	0.4395604	0.1960328	0.0028899
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
8	8	1.6949153	1.7582418	0.0633265	0.0298107
5	5	1.059322	1.0989011	0.0395791	0.0116448
1	1	0.2118644	0.2197802	0.0079158	0.0004658
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	1	0	0.2197802	0.2197802	0.0001208
2	1	0.4237288	0.2197802	0.2039486	0.0010353
7	7	1.4830508	1.5384615	0.0554107	0.0228238
3	3	0.6355932	0.6593407	0.0237474	0.0041921
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
1	1	0.2118644	0.2197802	0.0079158	0.0004658
2	2	0.4237288	0.4395604	0.0158316	0.0018632

1	1	0.2118644	0.2197802	0.0079158	0.0004658
3	3	0.6355932	0.6593407	0.0237474	0.0041921
3	3	0.6355932	0.6593407	0.0237474	0.0041921
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
6	6	1.2711864	1.3186813	0.0474949	0.0167685
5	5	1.059322	1.0989011	0.0395791	0.0116448
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	1	0	0.2197802	0.2197802	0.0001208
1	0	0.2118644	0	0.2118644	0.0001122
0	0	0	0	0	0
0	0	0	0	0	0
18	17	3.8135593	3.7362637	0.0772956	0.1424996
14	13	2.9661017	2.8571429	0.1089588	0.0847754
0	0	0	0	0	0
1	1	0.2118644	0.2197802	0.0079158	0.0004658
0	0	0	0	0	0
2	2	0.4237288	0.4395604	0.0158316	0.0018632
0	0	0	0	0	0
1	1	0.2118644	0.2197802	0.0079158	0.0004658
0	0	0	0	0	0
17	16	3.6016949	3.5164835	0.0852114	0.1266712
11	10	2.3305085	2.1978022	0.1327063	0.051264
3	3	0.6355932	0.6593407	0.0237474	0.0041921
2	1	0.4237288	0.2197802	0.2039486	0.0010353
0	1	0	0.2197802	0.2197802	0.0001208
1	1	0.2118644	0.2197802	0.0079158	0.0004658
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
30	30	6.3559322	6.5934066	0.2374744	0.4192134
19	19	4.0254237	4.1758242	0.1504004	0.1681512
5	5	1.059322	1.0989011	0.0395791	0.0116448
4	4	0.8474576	0.8791209	0.0316633	0.0074527
0	0	0	0	0	0
1	1	0.2118644	0.2197802	0.0079158	0.0004658
0	0	0	0	0	0
0	0	0	0	0	0
1	1	0.6024096	0.862069	0.2596593	0.0053617
19	18	4.0254237	3.956044	0.0693798	0.1592596
13	12	2.7542373	2.6373626	0.1168747	0.0726734
4	4	0.8474576	0.8791209	0.0316633	0.0074527
1	1	0.2118644	0.2197802	0.0079158	0.0004658
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
1	1	0.2118644	0.2197802	0.0079158	0.0004658
0	0	0	0	0	0
2	2	0.4237288	0.4395604	0.0158316	0.0018632
1	1	0.2118644	0.2197802	0.0079158	0.0004658
12	11	2.5423729	2.4175824	0.1247905	0.0615029

1	1	0.2118644	0.2197802	0.0079158	0.0004658
2	2	0.4237288	0.4395604	0.0158316	0.0018632
0	0	0	0	0	0
6	6	1.2711864	1.3186813	0.0474949	0.0167685
0	0	0	0	0	0
0	0	0	0	0	0
3	3	0.6355932	0.6593407	0.0237474	0.0041921
10	9	2.1186441	1.978022	0.1406221	0.0419567
1	1	0.2118644	0.2197802	0.0079158	0.0004658
2	2	0.4237288	0.4395604	0.0158316	0.0018632
2	2	0.4237288	0.4395604	0.0158316	0.0018632
9	7	1.9067797	1.5384615	0.3683181	0.0296742
0	0	0	0	0	0
2	3	0.4237288	0.6593407	0.2356118	0.0029326
2	1	0.4237288	0.2197802	0.2039486	0.0010353
7	5	1.4830508	1.0989011	0.3841497	0.0166662
5	5	1.059322	1.0989011	0.0395791	0.0116448
2	1	0.4237288	0.2197802	0.2039486	0.0010353
0	1	0	0.2197802	0.2197802	0.0001208
7	6	1.4830508	1.3186813	0.1643695	0.0196243
2	2	0.4237288	0.4395604	0.0158316	0.0018632
2	2	0.4237288	0.4395604	0.0158316	0.0018632
1	1	0.2118644	0.2197802	0.0079158	0.0004658
5	5	1.059322	1.0989011	0.0395791	0.0116448
8	5	1.6949153	1.0989011	0.5960142	0.0195135
2	2	0.4237288	0.4395604	0.0158316	0.0018632
2	2	0.4237288	0.4395604	0.0158316	0.0018632
4	4	0.8474576	0.8791209	0.0316633	0.0074527
2	2	0.4237288	0.4395604	0.0158316	0.0018632
2	2	0.4237288	0.4395604	0.0158316	0.0018632
2	2	0.4237288	0.4395604	0.0158316	0.0018632
1	1	0.2118644	0.2197802	0.0079158	0.0004658
4	4	0.8474576	0.8791209	0.0316633	0.0074527
1	2	0.2118644	0.4395604	0.227696	0.0010609
4	3	0.8474576	0.6593407	0.188117	0.0056761
6	5	1.2711864	1.0989011	0.1722853	0.0140433
2	2	0.4237288	0.4395604	0.0158316	0.0018632
1	1	0.2118644	0.2197802	0.0079158	0.0004658
1	1	0.2118644	0.2197802	0.0079158	0.0004658
3	2	0.6355932	0.4395604	0.1960328	0.0028899
1	1	0.2118644	0.2197802	0.0079158	0.0004658
0	0	0	0	0	0
3	2	0.6355932	0.4395604	0.1960328	0.0028899
2	3	0.4237288	0.6593407	0.2356118	0.0029326
0	0	0	0	0	0
472	**455**	**100.39055**	**100.64229**	**9.3493408**	**2.2116909**

3. Using Simple Plots

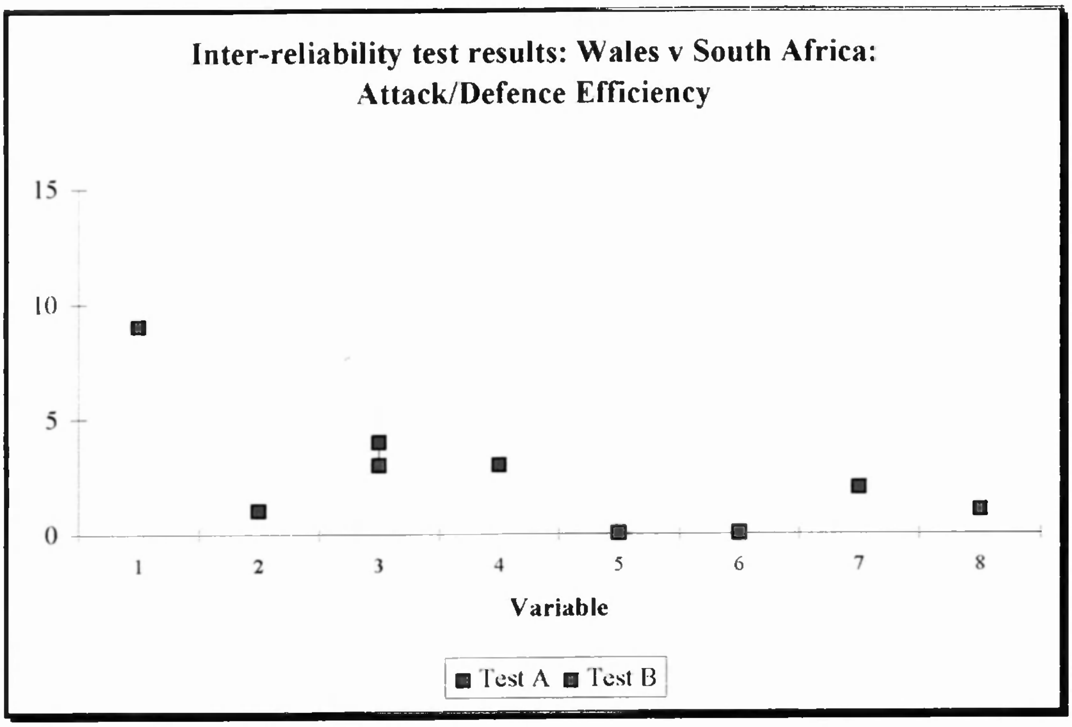

Figure B33: Plots of inter-reliability test for computer notation: Wales v S Africa

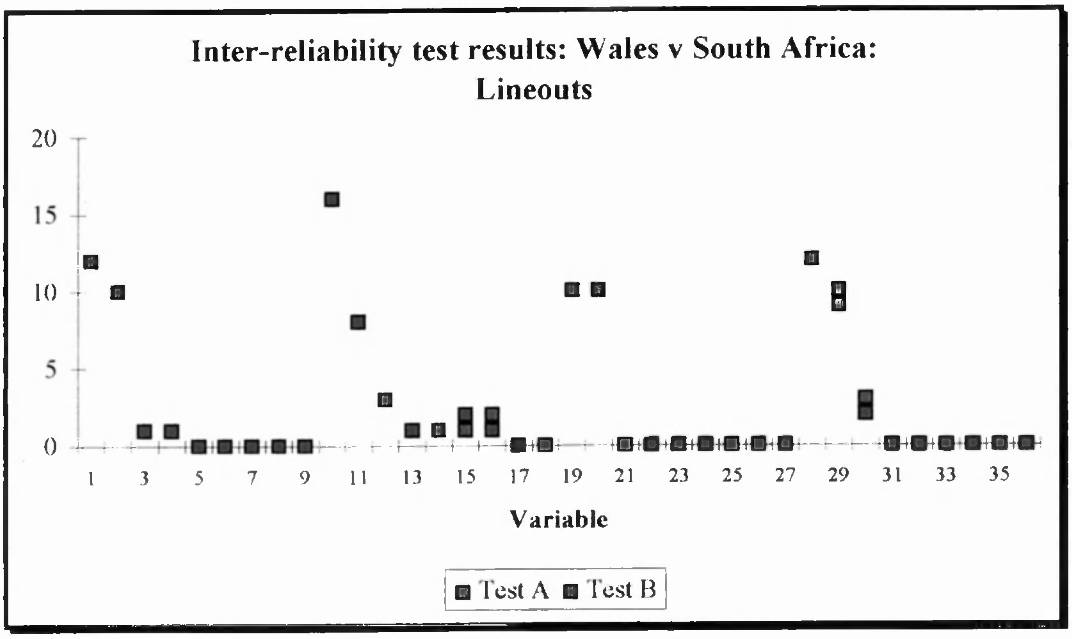

Figure B34: Plots of inter-reliability test for computer notation: Wales v S Africa

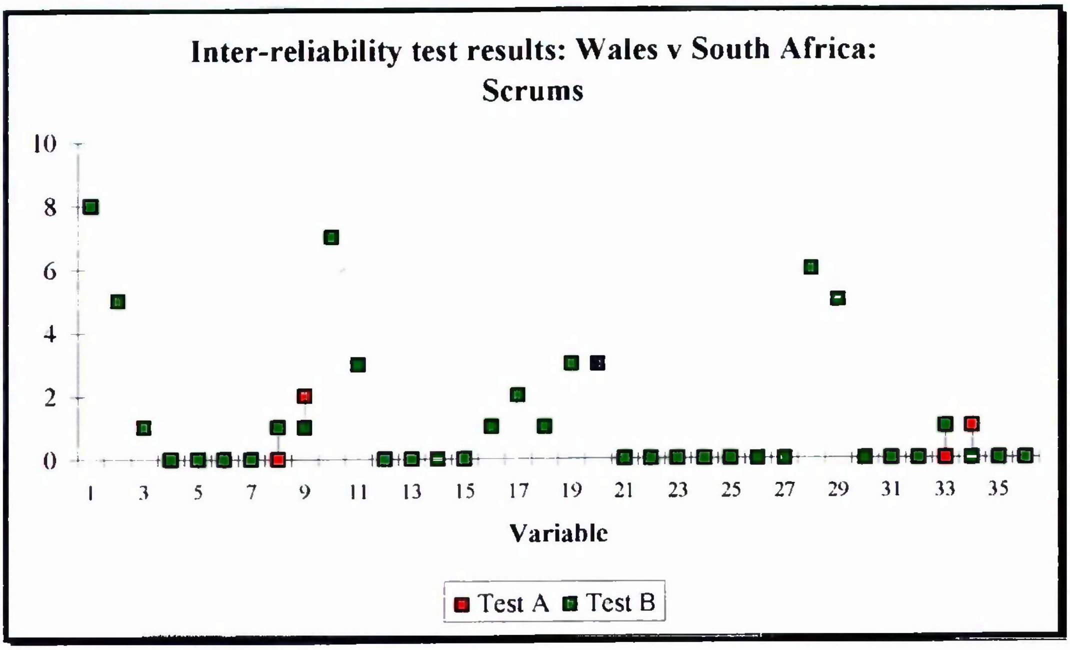

Figure B35: Plots of inter-reliability test for computer notation: Wales v S Africa

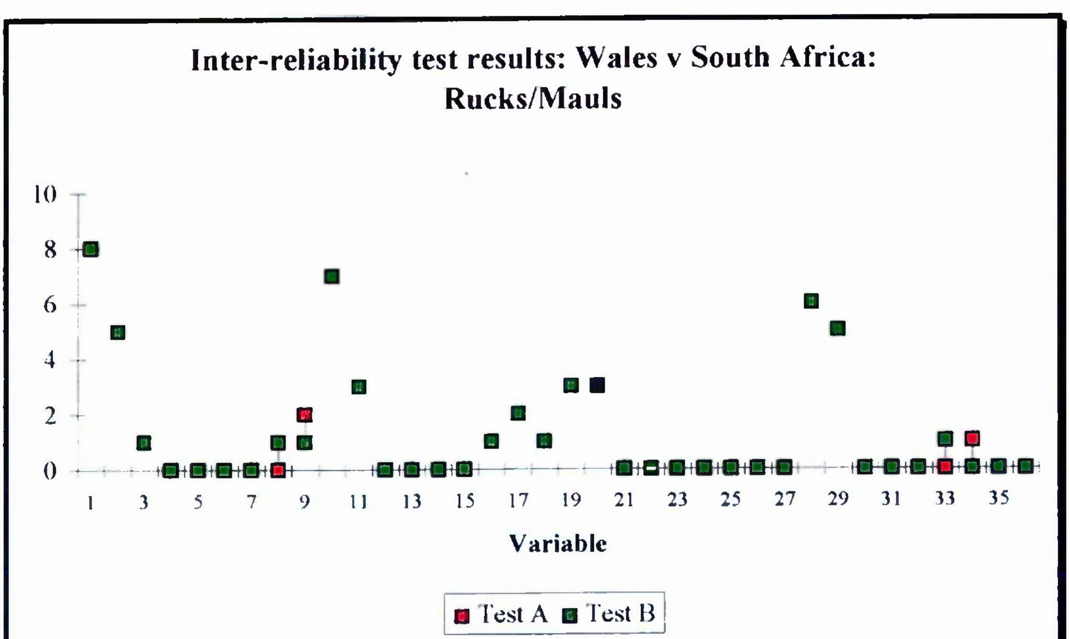

Figure B36: Plots of inter-reliability test for computer notation: Wales v S Africa

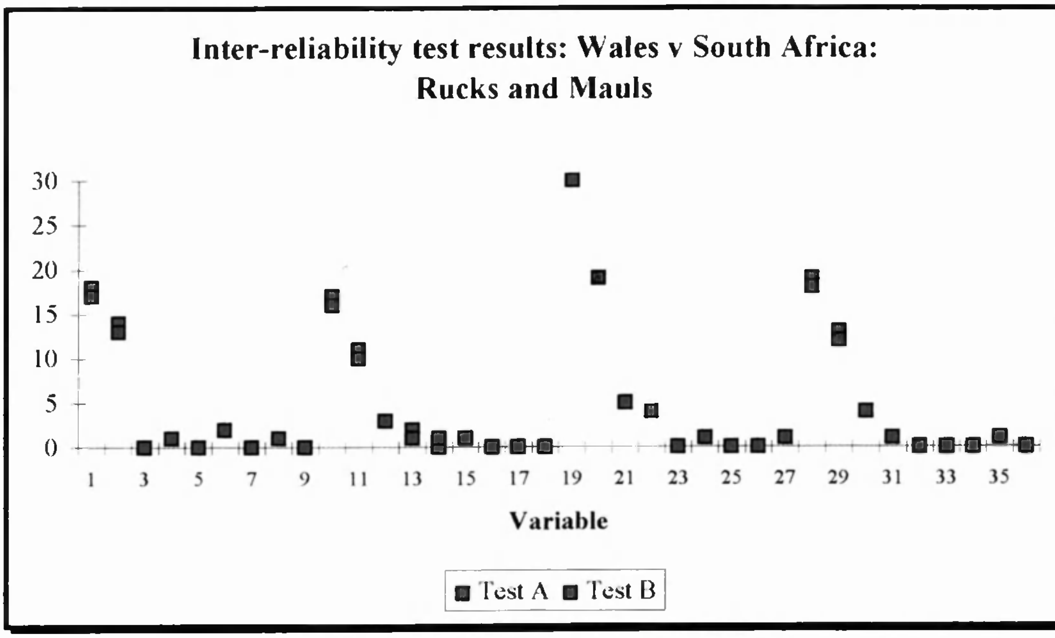

Figure B37: Plots of inter-reliability test for computer notation: Wales v S Africa

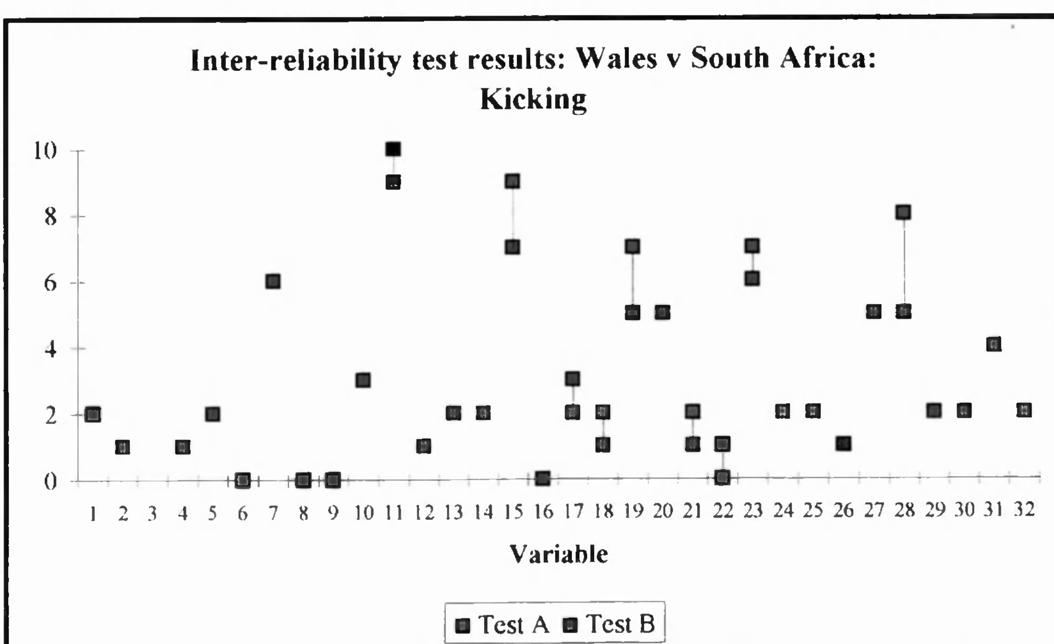

Figure B38: Plots of inter-reliability test for computer notation: Wales v S Africa

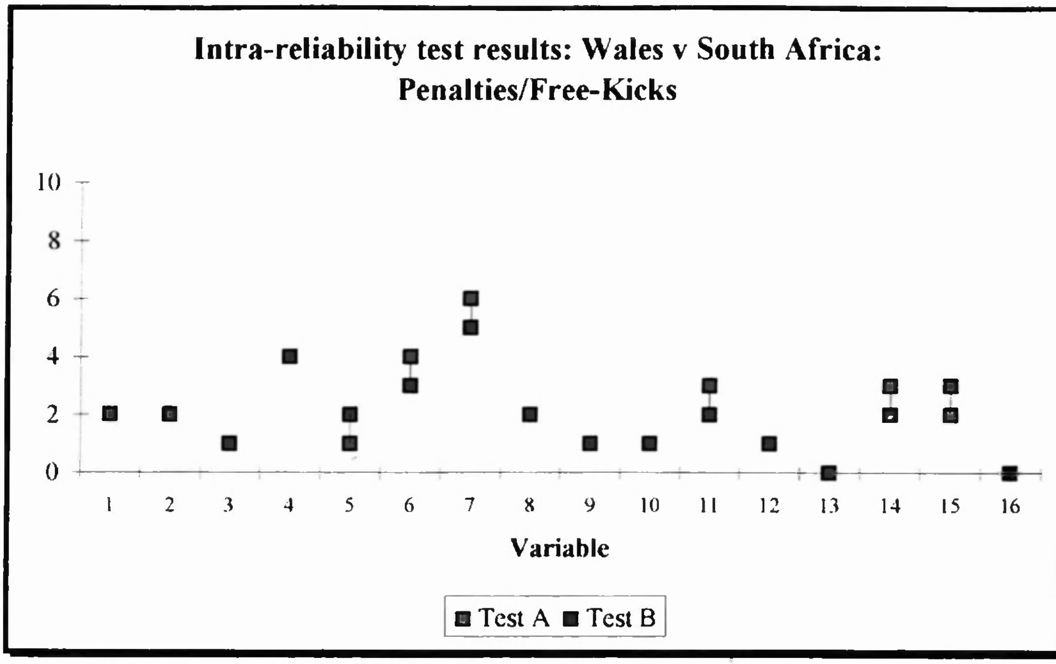

Figure B39: Plots of inter-reliability test for computer notation: Wales v S Africa

Appendix C

The Notation Systems

The research used both hand and computer notation. The hand notation systems were developed over a period of four years (1989-1993) to the current final stage which was used in the research). The hand notation systems were designed to collect data in real-time. The use of the hand notation systems was considered as necessary as part of the whole developmental process. They was tried and tested system which had been tested rigorously for both reliability and validity at an earlier stage. They thus provided a sound back-up system in case of any operational difficulties with the computer notation and ensured that the data collected by the computer notation was both reliable and valid. The hand notation was colour-coded according to teams so that the sequentiality of the events could be noted. The standard hand notation sheets and the hand notation sheets for both the rugby union and the soccer matches used in the reliability and validity test are shown on the following pages.

The computer notation systems were developed as an extension to the hand notation. They were programmed in the Visual Basic computer language. The computer notation was time-based. This had important implications because the data collected could now be related to the game situation in terms of both time and score. The computer analysis allows for the sequential history of the events to be logged.

A lapsed-time computer notation system was used to collect the individual player information on the sides in the 1995 Five Nations Championship. This was again programmed in the Visual Basic computer language.

For any further details regarding the computer programs used in the research the contact person and address is shown below:

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Rugby Union Analysis

Kicks			Passes				Lineouts	Scrums	P/FK	Inj	Drives		Rucks/Mauls	
1	51	101	1	51	101	151	1	1	1	1	1	51	1	51
2	52	102	2	52	102	152	2	2	2	2	2	52	2	52
3	53	103	3	53	103	153	3	3	3	3	3	53	3	53
4	54	104	4	54	104	154	4	4	4	4	4	54	4	54
5	55	105	5	55	105	155	5	5	5	5	5	55	5	55
6	56	106	6	56	106	156	6	6	6	6	6	56	6	56
7	57	107	7	57	107	157	7	7	7	7	7	57	7	57
8	58	108	8	58	108	158	8	8	8	8	8	58	8	58
9	59	109	9	59	109	159	9	9	9	9	9	59	9	59
10	60	110	10	60	110	160	10	10	10	10	10	60	10	60
11	61	111	11	61	111	161	11	11	11	11	11	61	11	61
12	62	112	12	62	112	162	12	12	12	12	12	62	12	62
13	63	113	13	63	113	163	13	13	13	13	13	63	13	63
14	64	114	14	64	114	164	14	14	14	14	14	64	14	64
15	65	115	15	65	115	165	15	15	15	15	15	65	15	65
16	66	116	16	66	116	166	16	16	16		16	66	16	66
17	67	117	17	67	117	167	17	17	17	Marks	17	67	17	67
18	68	118	18	68	118	168	18	18	18		18	68	18	68
19	69	119	19	69	119	169	19	19	19		19	69	19	69
20	70	120	20	70	120	170	20	20	20		20	70	20	70
21	71	121	21	71	121	171	21	21	21	1	21	71	21	71
22	72	122	22	72	122	172	22	22	22	2	22	72	22	72
23	73	123	23	73	123	173	23	23	23	3	23	73	23	73
24	74	124	24	74	124	174	24	24	24	4	24	74	24	74
25	75	125	25	75	125	175	25	25	25	5	25	75	25	75
26	76	126	26	76	126	176	26	26	26		26	76	26	76
27	77	127	27	77	127	177	27	27	27	Turnovers	27	77	27	77
28	78	128	28	78	128	178	28	28	28		28	78	28	78
29	79	129	29	79	129	179	29	29	29		29	79	29	79
30	80	130	30	80	130	180	30	30	30		30	80	30	80
31	81	131	31	81	131	181	31	31	31	1	31	81	31	81
32	82	132	32	82	132	182	32	32	32	2	32	82	32	82
33	83	133	33	83	133	183	33	33	33	3	33	83	33	83
34	84	134	34	84	134	184	34	34	34	4	34	84	34	84
35	85	135	35	85	135	185	35	35	35	5	35	85	35	85
36	86	136	36	86	136	186	36	36	36	6	36	86	36	86
37	87	137	37	87	137	187	37	37	37	7	37	87	37	87
38	88	138	38	88	138	188	38	38	38	8	38	88	38	88
39	89	139	39	89	139	189	39	39	39	9	39	89	39	89
40	90	140	40	90	140	190	40	40	40	10	40	90	40	90
41	91	141	41	91	141	191	41	41	41	11	41	91	41	91
42	92	142	42	92	142	192	42	42	42	12	42	92	42	92
43	94	143	43	94	143	194	43	43	43	13	43	94	43	94
44	94	144	44	94	141	194	44	44	44	14	44	94	44	94
45	95	145	45	95	145	195	45	45	45	15	45	95	45	95
46	96	146	46	96	146	196	46	46	46	16	46	96	46	96
47	97	147	47	97	147	197	47	47	47	17	47	97	47	97
48	98	148	48	98	148	198	48	48	48	18	48	98	48	98
49	99	149	49	99	149	199	49	49	49	19	49	99	49	99
50	100	150	50	100	150	200	50	50	50	20	50	100	50	100

LO Jumpers	
4	
4	
5	
5	
6	
6	
8	
8	
7	
7	

	Passing Share			Lineout Share			Lineout Success			Scrum Share			Scrum Success			Poss. share		
	Passing Share			Lineout Share			Lineout Success			Scrum Share			Scrum Success			Poss. share		

Match		Venue		Match time	1st half		2nd half		Total
Date		Referee		Ball in Play	1st half		2nd Half		Total
Half-time Score		Conditions		Territorial (time)	1st half		2nd half		Total
Full-time Score		Try-scorers		Territorial (%)	1st half		2nd half		Total

Restarts								Tackling							
Successful		Unsuccessful		Successful		Unsuccessful		Successful		Unsuccessful		Successful		Unsuccessful	

Outside-half	Kicks	Pass	Run	Tackled	Errors	K-ons	O-side	Miss tch	Out full	For-pass	Goal-kicks	Pens	Cons	D-gls	Total

Outside-half	Kicks	Pass	Run	Tackled	Errors	K-ons	O-side	Miss tch	Out full	For-pass	Goal-kicks	Pens	Cons	D-gls	Total

Continuity							
	1st half	2nd half	Total		1st half	2nd half	Total
1st phase				1st phase			
2nd phase				2nd phase			
3rd phase				3rd phase			
4th+ phase				4th+ phase			

Soccer Analysis

Match	
Date	
Time	
Venue	
Referee	
Conds	

Team Sheet

Number		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		

	1st half	2nd half	Total
Match-time			
	1st half	2nd half	Total
Ball in Play time			

Half-time Score	
Full-time Score	

Goal-scorers and time	1	2	3	4	5	6	7	8

Soccer Analysis

Passes						Passes						FK/Pen	Throws	Corners	Injuries
1	51	101	151	201	251	1	51	101	151	201	251	1	1	1	1
2	52	102	152	202	252	2	52	102	152	202	252	2	2	2	2
3	53	103	153	203	253	3	53	103	153	203	253	3	3	3	3
4	54	104	154	204	254	4	54	104	154	204	254	4	4	4	4
5	55	105	155	205	255	5	55	105	155	205	255	5	5	5	5
6	56	106	156	206	256	6	56	106	156	206	256	6	6	6	6
7	57	107	157	207	257	7	57	107	157	207	257	7	7	7	7
8	58	108	158	208	258	8	58	108	158	208	258	8	8	8	8
9	59	109	159	209	259	9	59	109	159	209	259	9	9	9	9
10	60	110	160	210	260	10	60	110	160	210	260	10	10	10	10
11	61	111	161	211	261	11	61	111	161	211	261	11	11	11	11
12	62	112	162	212	262	12	62	112	162	212	262	12	12	12	12
13	63	113	163	213	263	13	63	113	163	213	263	13	13	13	13
14	64	114	164	214	264	14	64	114	164	214	264	14	14	14	14
15	65	115	165	215	265	15	65	115	165	215	265	15	15	15	15
16	66	116	166	216	266	16	66	116	166	216	266	16	16	16	
17	67	117	167	217	267	17	67	117	167	217	267	17	17	17	
18	68	118	168	218	268	18	68	118	168	218	268	18	18	18	
19	69	119	169	219	269	19	69	119	169	219	269	19	19	19	
20	70	120	170	220	270	20	70	120	170	220	270	20	20	20	Goal-kicks
21	71	121	171	221	271	21	71	121	171	221	271	21	21	21	1
22	72	122	172	222	272	22	72	122	172	222	272	22	22	22	2
23	73	123	173	223	273	23	73	123	173	223	273	23	23	23	3
24	74	124	174	224	274	24	74	124	174	224	274	24	24	24	4
25	75	125	175	225	275	25	75	125	175	225	275	25	25	25	5
26	76	126	176	226	276	26	76	126	176	226	276	26	26	26	6
27	77	127	177	227	277	27	77	127	177	227	277	27	27	27	7
28	78	128	178	228	278	28	78	128	178	228	278	28	28	28	8
29	79	129	179	229	279	29	79	129	179	229	279	29	29	29	9
30	80	130	180	230	280	30	80	130	180	230	280	30	30	30	10
31	81	131	181	231	281	31	81	131	181	231	281	31	31	31	11
32	82	132	182	232	282	32	82	132	182	232	282	32	32	32	12
33	83	133	183	233	283	33	83	133	183	233	283	33	33	33	13
34	84	134	184	234	284	34	84	134	184	234	284	34	34	34	14
35	85	135	185	235	285	35	85	135	185	235	285	35	35	35	15
36	86	136	186	236	286	36	86	136	186	236	286	36	36	36	16
37	87	137	187	237	287	37	87	137	187	237	287	37	37	37	17
38	88	138	188	238	288	38	88	138	188	238	288	38	38	38	18
39	89	139	189	239	289	39	89	139	189	239	289	39	39	39	19
40	90	140	190	240	290	40	90	140	190	240	290	40	40	40	20
41	91	141	191	241	291	41	91	141	191	241	291	41	41	41	21
42	92	142	192	242	292	42	92	142	192	242	292	42	42	42	22
43	93	143	193	243	293	43	93	143	193	243	293	43	43	43	23
44	94	144	194	244	294	44	94	144	194	244	294	44	44	44	24
45	95	145	195	245	295	45	95	145	195	245	295	45	45	45	25
46	96	146	196	246	296	46	96	146	196	246	296	46	46	46	26
47	97	147	197	247	297	47	97	147	197	247	297	47	47	47	27
48	98	148	198	248	298	48	98	148	198	248	298	48	48	48	28
49	99	149	199	249	299	49	99	149	199	249	299	49	49	49	29
50	100	150	200	250	300	50	100	150	200	250	300	50	50	50	30

Soccer Analysis

Goal-keeper Option

Name	Long kicks		Short kicks/Throws	

Errors

Team	Fouls	Off-sides	Hand-balls	YC	RC

Shooting

Team	On	Off	Goals	Total

Top Shooters

Player	Shots	Player	Shots

Continuity

No of Passes	1H	2H	Total	1H	2H	Total
0 to 3						
4 to 7						
8 to 11						
12 or more						

Rugby Union Analysis

Kicks		Passes		Lineouts		Scrums		P/FK (con)		Injuries		Drives		Rucks/Mauls	
101		161		50		24		33		4		33		63	
58	43	101	60	22	28	10	14	15	18	3	1	16	17	36	27

LO Jumpers

WALES	Lineout Share	22/50	44	Lineout Success	20/22	91	Scrum Share	10/24	42	Scrum Success	7/10	70	Passing Share	101/161	63	P/FK Share	15/33	45
S AFRICA	Lineout Share	28/50	56	Lineout Success	17/28	61	Scrum Share	14/24	58	Scrum Success	8/14	57	Passing Share	60/161	37	P/FK Share	18/33	55

Match	WALES v S AFRICA	Venue	CARDIFF	Match time	1st half	42:35	2nd half	61:09	Total	[illegible]
	26.11.96	Referee	[illegible]	Ball in Play	1st half	11:55	2nd Half	13:17	Total	25:13
Score	6 · 10	Conditions	[illegible]	Territorial (time)	1st half	[illegible]	2nd half	[illegible]	Total	[illegible]
Full-time Score	11 · 20	Try-scorers	[illegible]	Territorial (%)	1st half	[illegible]	2nd half	[illegible]	Total	[illegible]

Tackling

65/76 = 87·86	WALES			S AFRICA	75/83 = 90·36%		
Successful		Unsuccessful		Successful		Unsuccessful	
28	37	6	3	36	39	4	4

Restarts	H-Way	22 metre	H-Way	22 metre	Errors	K-ons	Miss tch	Out full	For-pass	Not Str	Goal-kicks	Pens	Cons	D-gls	Total
WALES 5/8 = 62·5%	1	1	1	2	WALES	4	1	3	0	0	[illegible]	✓✓✗✓			4/5
	✗✗ 2	0	✗ [illegible]	0		4	0	1	0	0		✓ 4/5			80%
Restarts	H-Way	22 metre	H-Way	22 metre	Errors	K-ons	Miss tch	Out full	For-pass	Not Str	Goal-kicks	Pens	Cons	D-gls	Total
S AFRICA 4/5 = 80%	2	0	✓✓ 2	0	S AFRICA	2	0	0	0	0	H. SCHOLTZ	✗ 0/1	✗✗ 0/2		2/7
	0	0	✗	0		3	0	1	0	0	[illegible]	✓✗ 1/2	✓ 1/1	✗ 0/1	28·57%

Continuity

WALES	1st half	2nd half	Total	S AFRICA	1st half	2nd half	Total
1st phase	20	19	39	1st phase	13	15	28
2nd phase	7	4	11	2nd phase	4	6	10
3rd phase	1	2	3	3rd phase	0	1	1
4th+ phase	1	2	3	4th+ phase	2	2	4

Soccer Analysis

Match	DENMARK v GERMANY
Date	26 /6 /92
Time	–
Venue	GOTHENBURG
Referee	BRUNO GALLER (SWITZERLAND)
Conds	DRY

Team Sheet

Number	DENMARK	GERMANY
1	SCHMEICHEL	ILLGNER
2	SIVAEBECK *	HELMER
3	NIELSEN	REUTER
4	OLSEN	KOHLER
5	PIECHNIK	BUCHWALD
6	CHRISTOFTE	BREHME
7	JENSEN	HASSLER
8	VILLFORT	SAMMER *
9	LARSEN	EFFENBURG +
10	POULSEN	RIEDLE
11	LAUDRUP	KLINSMANN
12	CHRISTIANSEN * (2H 22)	DOLL * (HT)
13	–	THOM + (2H 36)

	1st half	2nd half	Total
Match-time	46 : 09	46 : 04	92 : 13
	1st half	2nd half	Total
Ball in Play time	29 : 39	25 : 14	54 : 53

Half-time Score	1-0
Full-time Score	2-0

Goal-scorers and time	1	2	3	4	5	6	7	8
DENMARK	JENSEN (19)	VILFORT (80)						
GERMANY								

Soccer Analysis

569												51	35	14	7
206						363						24 27	13 22	4 10	6 1
132			74			180			183			12 12 11 16	8 5 10 12	3 1 5 5	2 4 1 0
Passes						Passes						FK/Pen	Throws	Corners	Injuries
1	51	101	151	201	251	1	51	101	151	201	251	1	1	1	1
2	52	102	152	202	252	2	52	102	152	202	252	2	2	2	2
3	53	103	153	203	253	3	53	103	153	203	253	3	3	3	3
4	54	104	154	204	254	4	54	104	154	204	254	4	4	4	4
5	55	105	155	205	255	5	55	105	155	205	255	5	5	5	5
6	56	106	156	206	256	6	56	106	156	206	256	6	6	6	6
7	57	107	157	207	257	7	57	107	157	207	257	7	7	7	7
8	58	108	158	208	258	8	58	108	158	208	258	8	8	8	8
9	59	109	159	209	259	9	59	109	159	209	259	9	9	9	9
10	60	110	160	210	260	10	60	110	160	210	260	10	10	10	10
11	61	111	161	211	261	11	61	111	161	211	261	11	11	11	11
12	62	112	162	212	262	12	62	112	162	212	262	12	12	12	12
13	63	113	163	213	263	13	63	113	163	213	263	13	13	13	13
14	64	114	164	214	264	14	64	114	164	214	264	14	14	14	14
15	65	115	165	215	265	15	65	115	165	215	265	15	15	15	15
16	66	116	166	216	266	16	66	116	166	216	266	16	16	16	
17	67	117	167	217	267	17	67	117	167	217	267	17	17	17	12
18	68	118	168	218	268	18	68	118	168	218	268	18	18	18	8 4
19	69	119	169	219	269	19	69	119	169	219	269	19	19	19	2 6 3 1
20	70	120	170	220	270	20	70	120	170	220	270	20	20	20	G-kicks
21	71	121	171	221	271	21	71	121	171	221	271	21	21	21	1
22	72	122	172	222	272	22	72	122	172	222	272	22	22	22	2
23	73	123	173	223	273	23	73	123	173	223	273	23	23	23	3
24	74	124	174	224	274	24	74	124	174	224	274	24	24	24	4
25	75	125	175	225	275	25	75	125	175	225	275	25	25	25	5
26	76	126	176	226	276	26	76	126	176	226	276	26	26	26	6
27	77	127	177	227	277	27	77	127	177	227	277	27	27	27	7
28	78	128	178	228	278	28	78	128	178	228	278	28	28	28	8
29	79	129	179	229	279	29	79	129	179	229	279	29	29	29	9
30	80	130	180	230	280	30	80	130	180	230	280	30	30	30	10
31	81	131	181	231	281	31	81	131	181	231	281	31	31	31	11
32	82	132	182	232	282	32	82	132	182	232	282	32	32	32	12
33	83	133	183	233	283	33	83	133	183	233	283	33	33	33	13
34	84	134	184	234	284	34	84	134	184	234	284	34	34	34	14
35	85	135	185	235	285	35	85	135	185	235	285	35	35	35	15
36	86	136	186	236	286	36	86	136	186	236	286	36	36	36	16
37	87	137	187	237	287	37	87	137	187	237	287	37	37	37	17
38	88	138	188	238	288	38	88	138	188	238	288	38	38	38	18
39	89	139	189	239	289	39	89	139	189	239	289	39	39	39	19
40	90	140	190	240	290	40	90	140	190	240	290	40	40	40	20
41	91	141	191	241	291	41	91	141	191	241	291	41	41	41	21
42	92	142	192	242	292	42	92	142	192	242	292	42	42	42	22
43	93	143	193	243	293	43	93	143	193	243	293	43	43	43	23
44	94	144	194	244	294	44	94	144	194	244	294	44	44	44	24
45	95	145	195	245	295	45	95	145	195	245	295	45	45	45	25
46	96	146	196	246	296	46	96	146	196	246	296	46	46	46	26
47	97	147	197	247	297	47	97	147	197	247	297	47	47	47	27
48	98	148	198	248	298	48	98	148	198	248	298	48	48	48	28
49	99	149	199	249	299	49	99	149	199	249	299	49	49	49	29
50	100	150	200	250	300	50	100	150	200	250	300	50	50	50	30

Soccer Analysis

Goal-keeper Option

Name	Long kicks		Short kicks/Throws	
SCHMEICHEL		20		10
		15		4
ILLGNER		2		8
		1		8

Errors

Team	Fouls	Off-sides	Hand-balls	YC	RC
DENMARK	11	1	0	1	0
	10	2	0	0	0
GERMANY	7	4	0	2	0
	13	3	0	3	0

Shooting

Team	On	Off	Goals	Total
DENMARK	1	2	1	4
	0	3	1	4
GERMANY	6	2	0	8
	1	6	0	7

Top Shooters

Player	Shots	Player	Shots

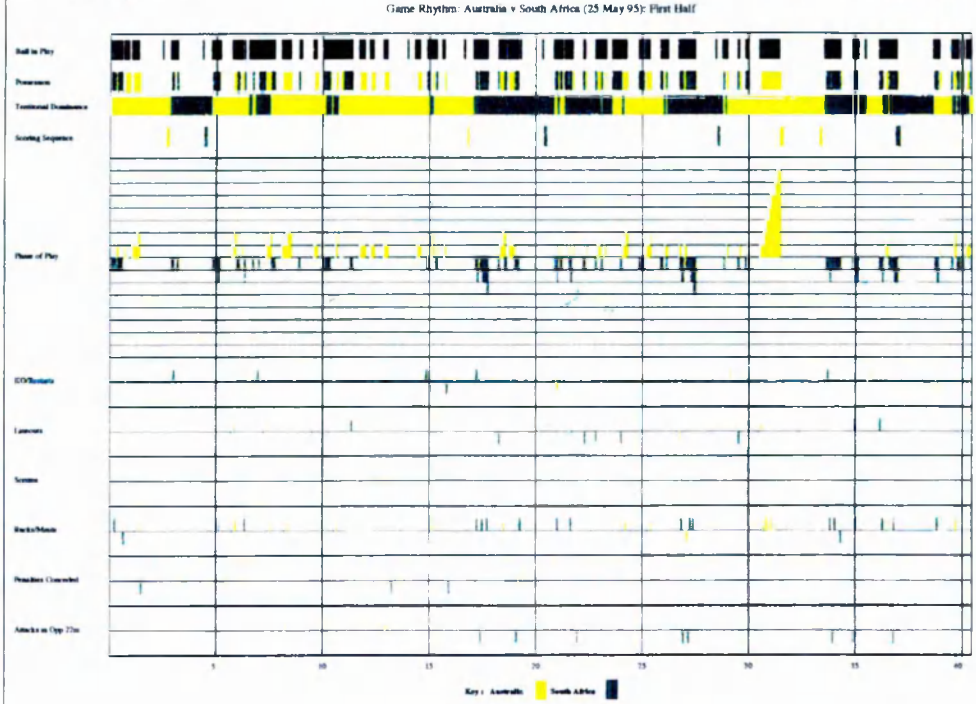
Continuity

No of Passes	1H	2H	Total	1H	2H	Total
0 to 3			63			86
4 to 7			11			34
8 to 11			1			2
12 or more			0			1

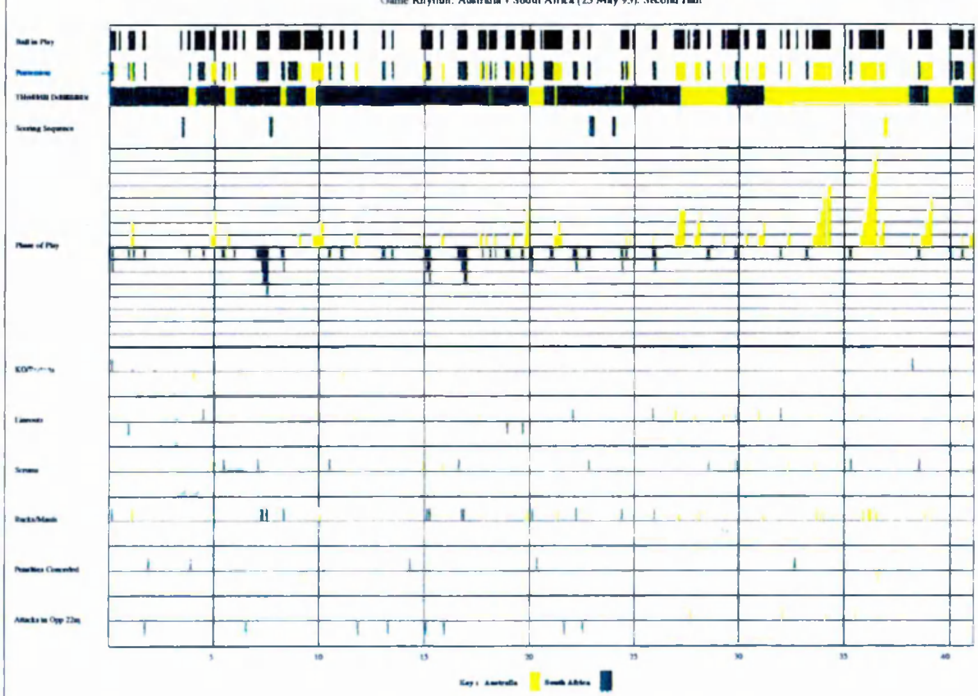
Appendix D

The game rhythm charts included in this Appendix are examples of both the rugby union and soccer charts from the Rugby World Cup '95, the Five Nations '96 and Euro '96. The fist game rhythm chart, Australia v South Africa was the first game of the 1995 Rugby World Cup and was the pilot study for the game rhythm charts which was discussed in Chapter Three.

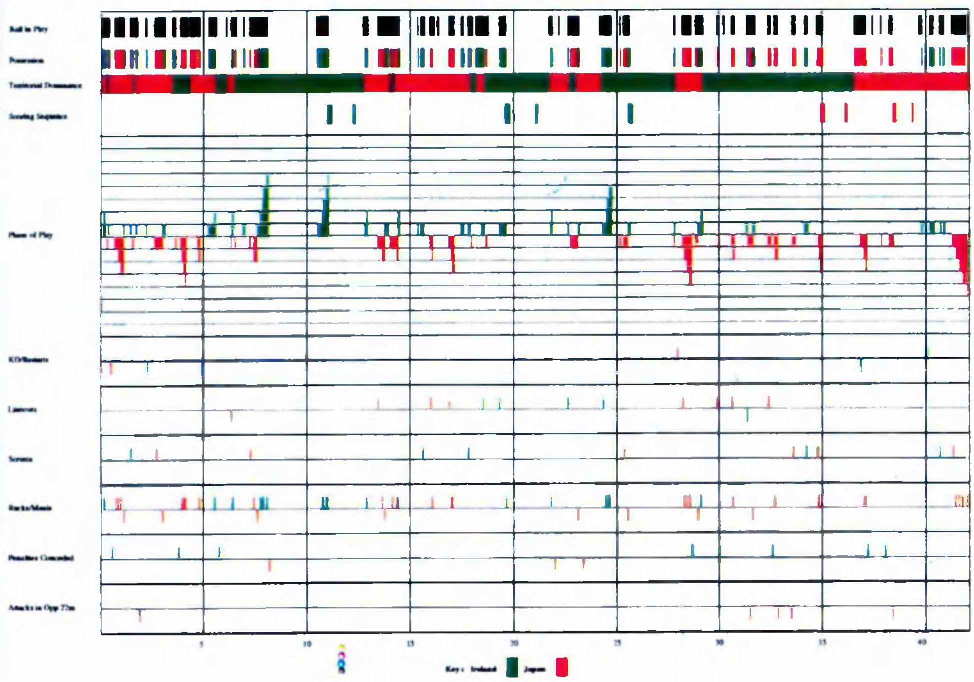
Game Rhythm: Australia v South Africa (25 May 95): First Half



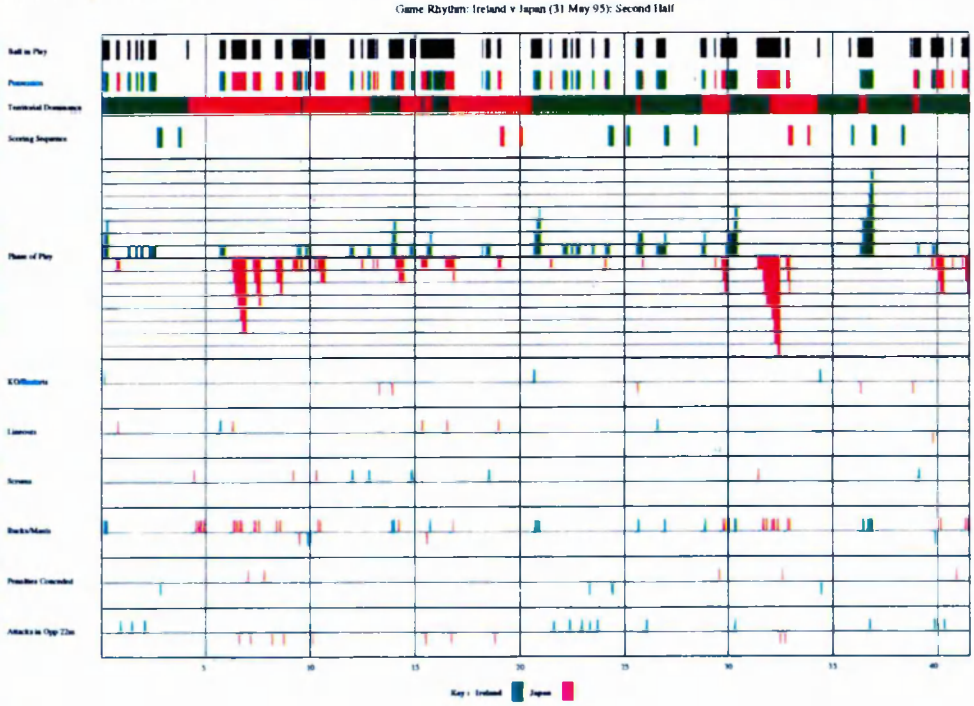
Game Rhythm: Australia v South Africa (25 May 95): Second Half



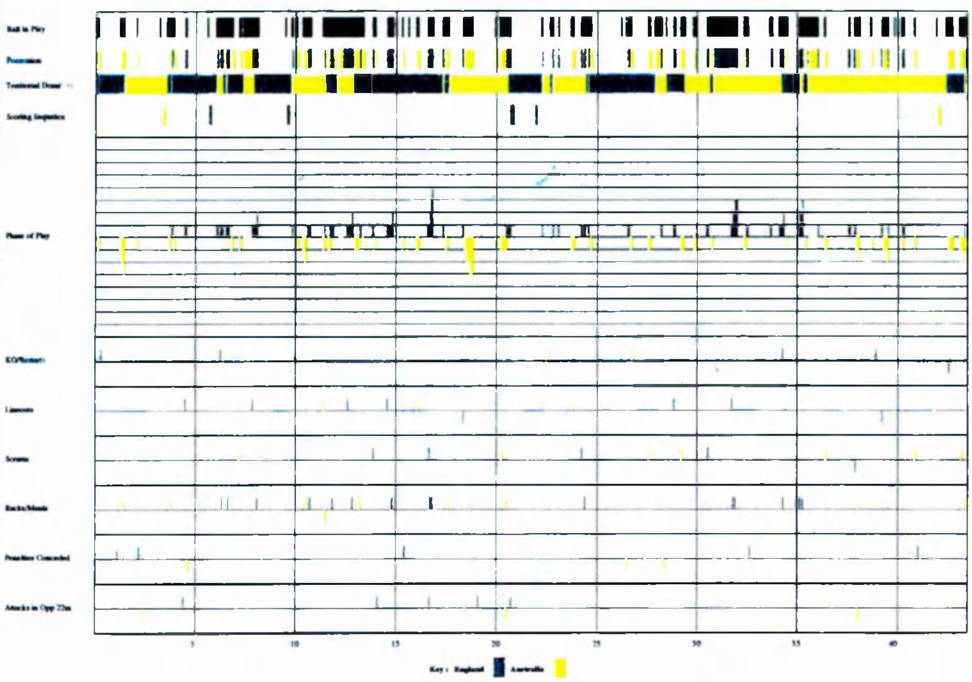
Game Rhythm: Ireland v Japan (31 May 95): First Half



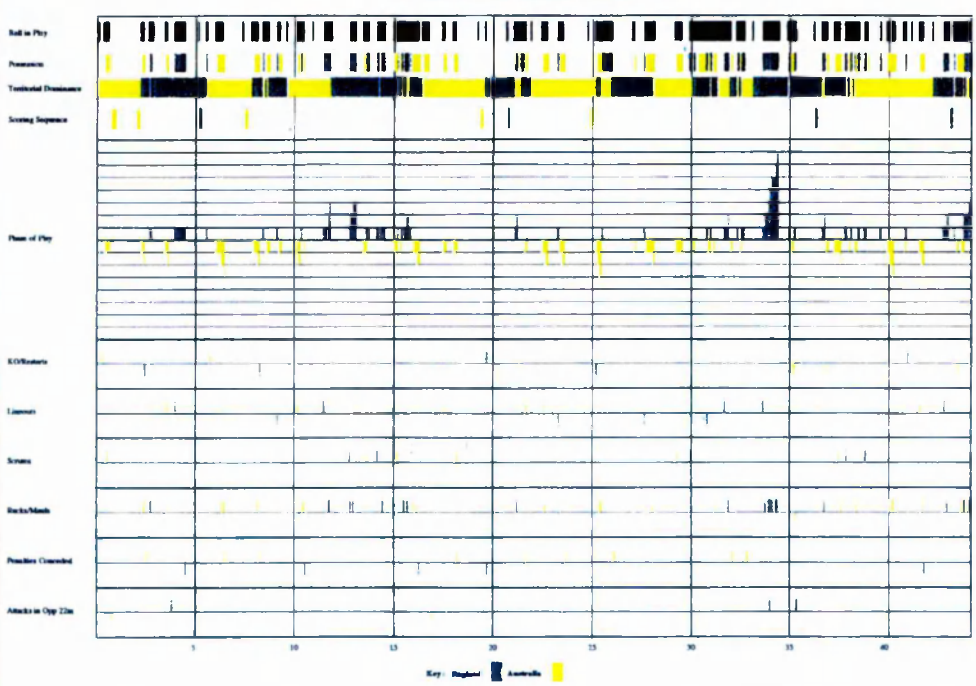
Game Rhythm: Ireland v Japan (31 May 95): Second Half



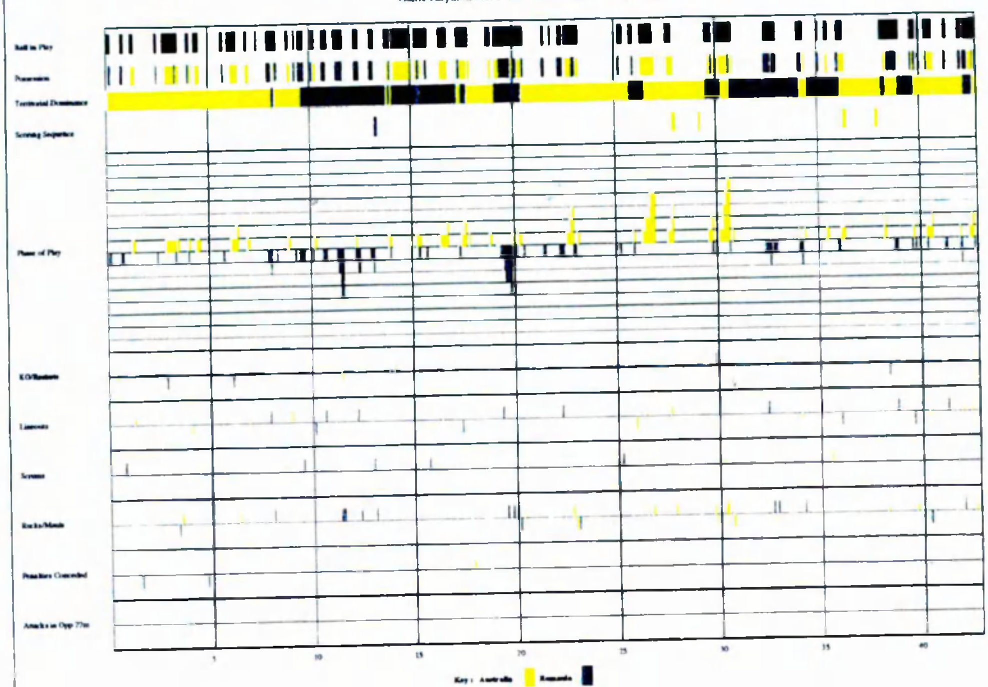
Game Rhythm: England v Australia (11 Jun 95): First Half



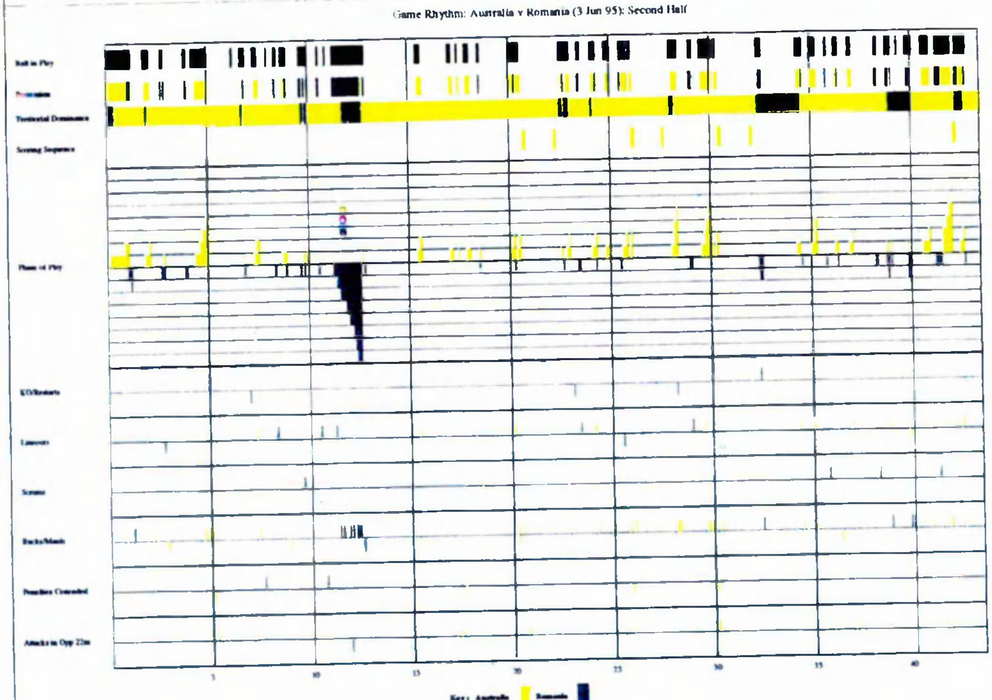
Game Rhythm: England v Australia (11 Jun 95): Second Half



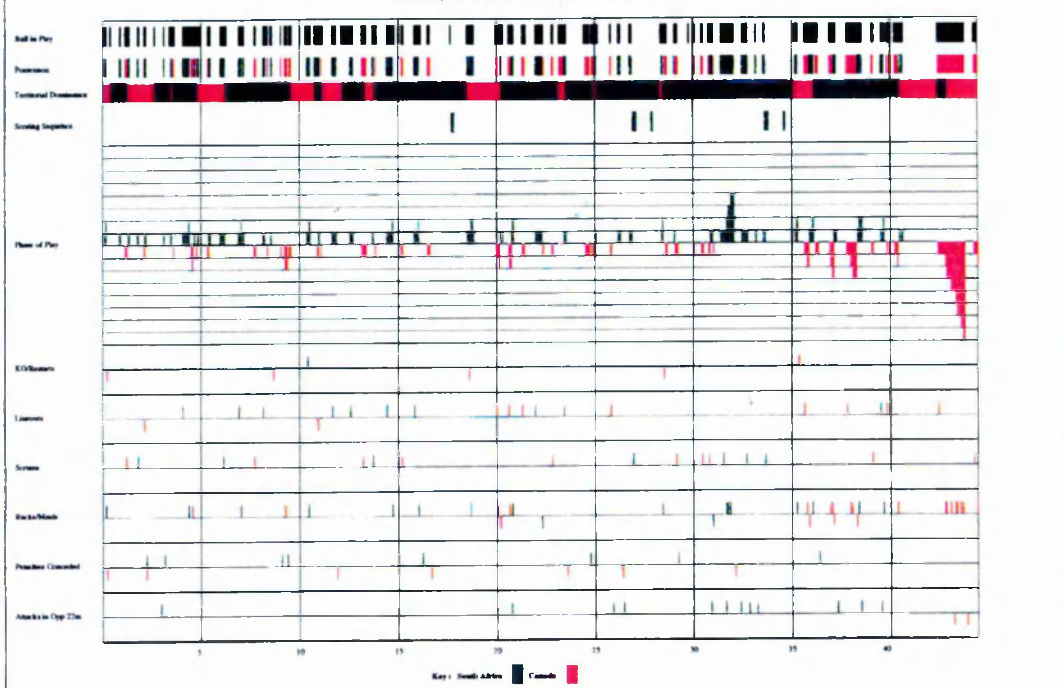
Game Rhythm: Australia v Romania (3 Jun 95): First Half



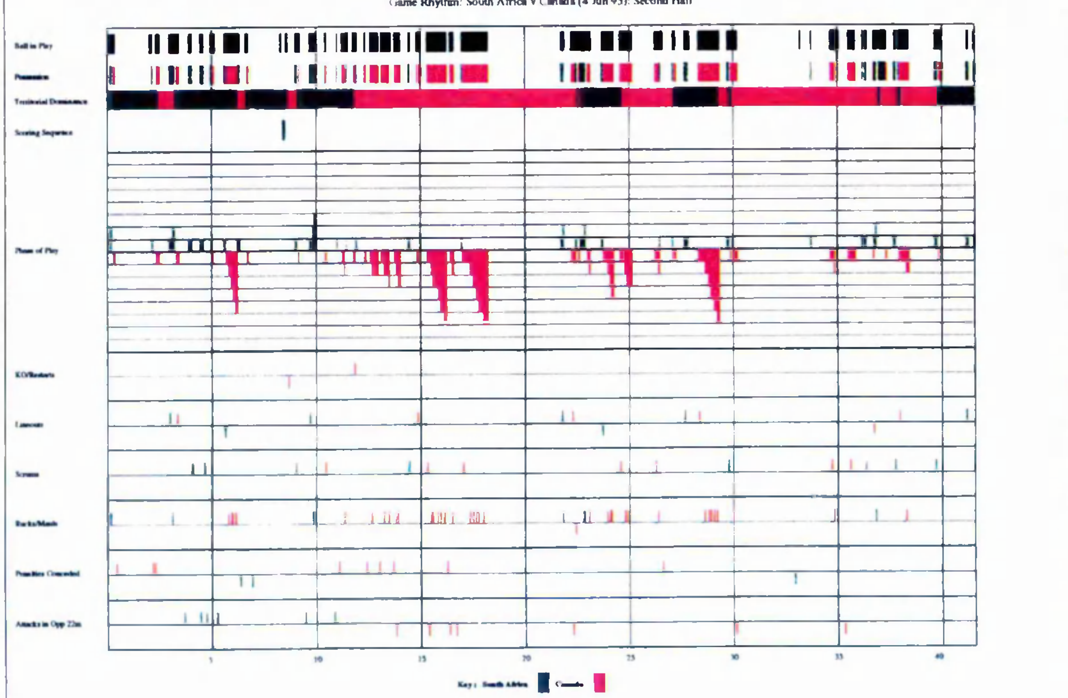
Game Rhythm: Australia v Romania (3 Jun 95): Second Half



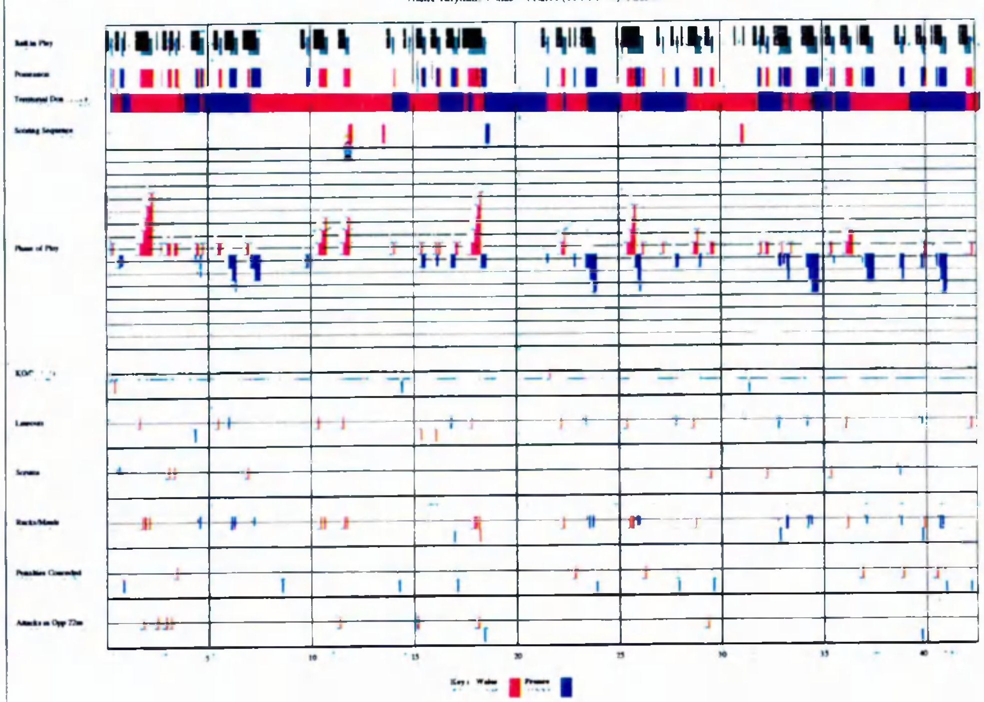
Game Rhythm: South Africa v Canada (4 Jun 95): First Half



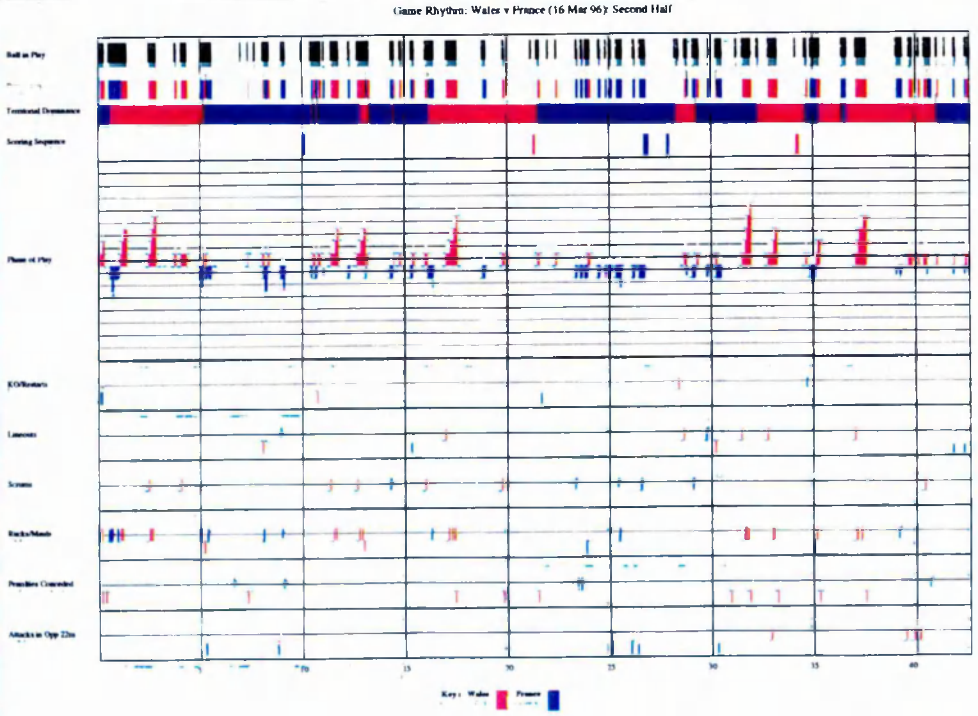
Game Rhythm: South Africa v Canada (4 Jun 95): Second Half



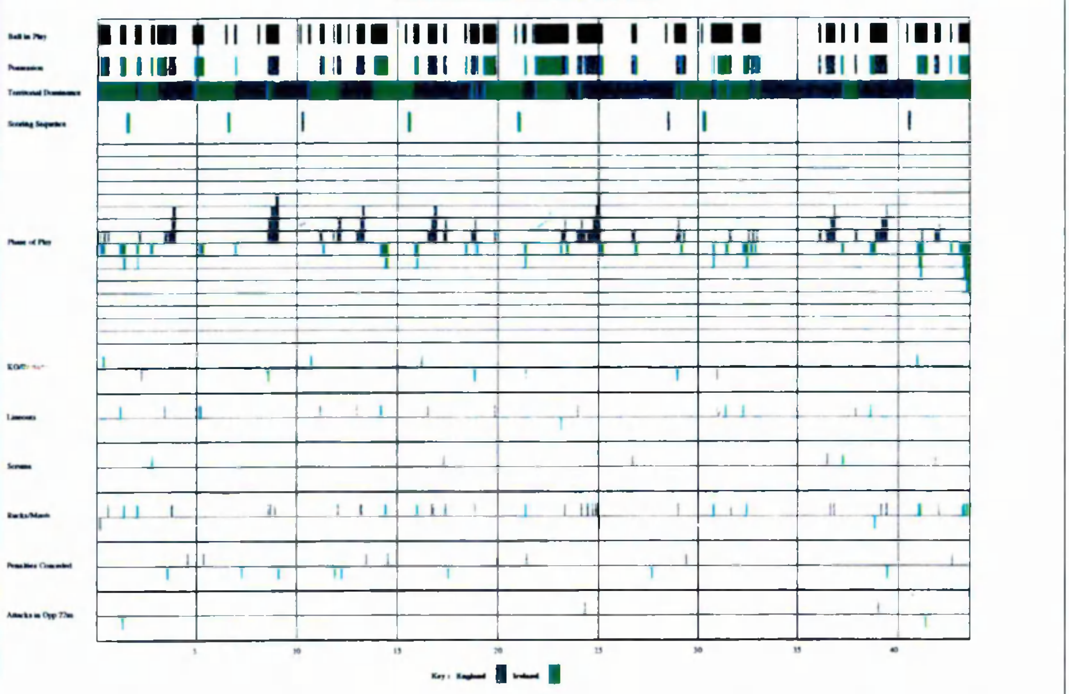
Game Rhythm: Wales v France (16 Mar 96): First Half



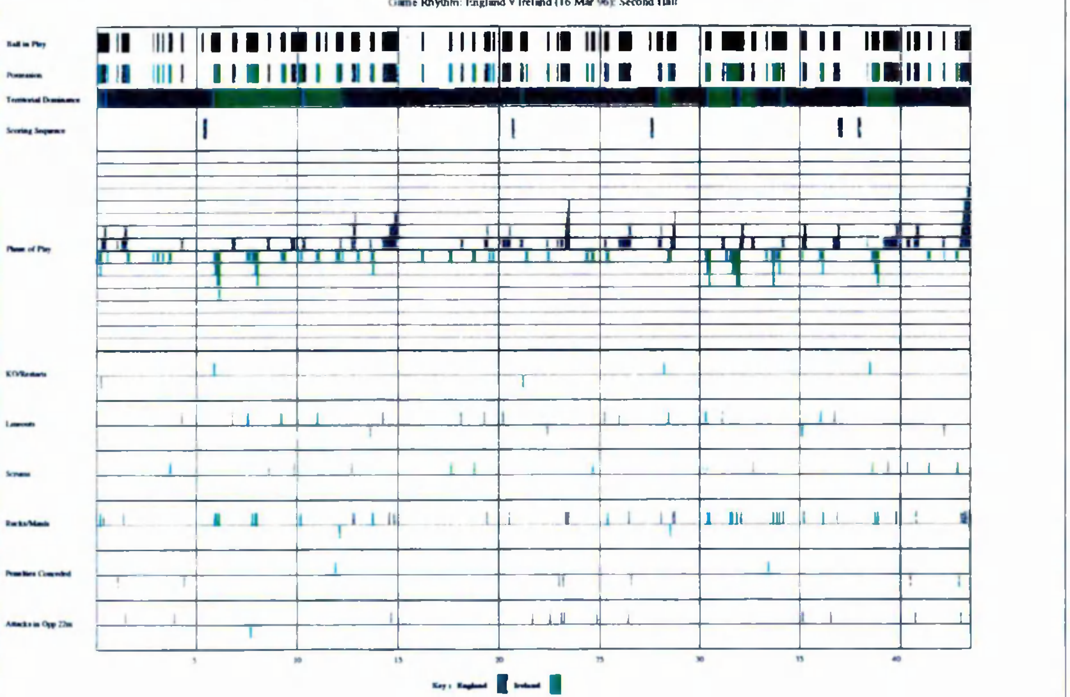
Game Rhythm: Wales v France (16 Mar 96): Second Half



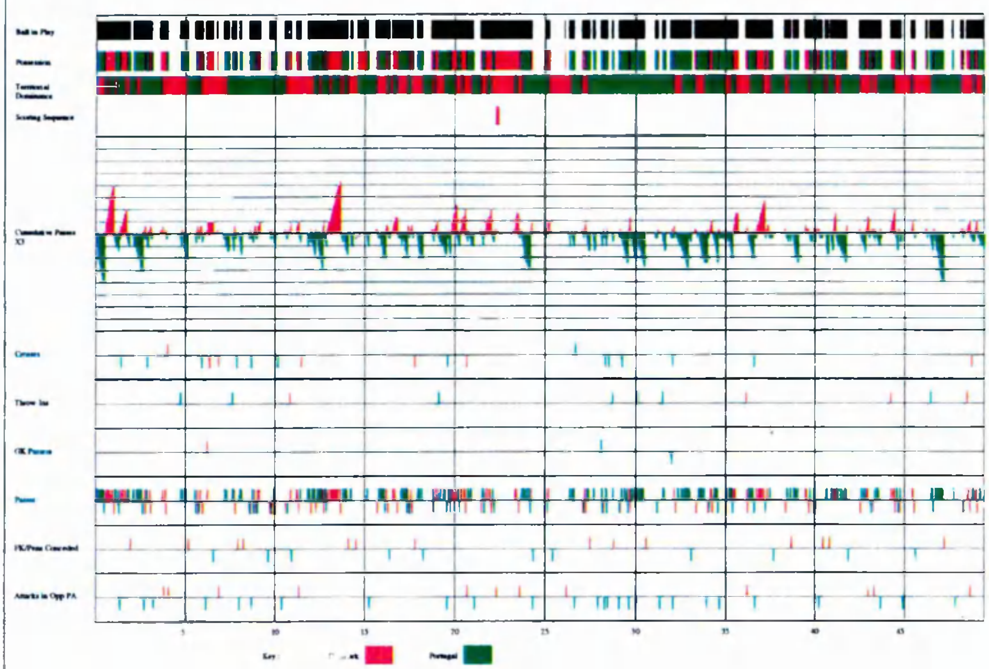
Game Rhythm: England v Ireland (16 Mar 96): First Half



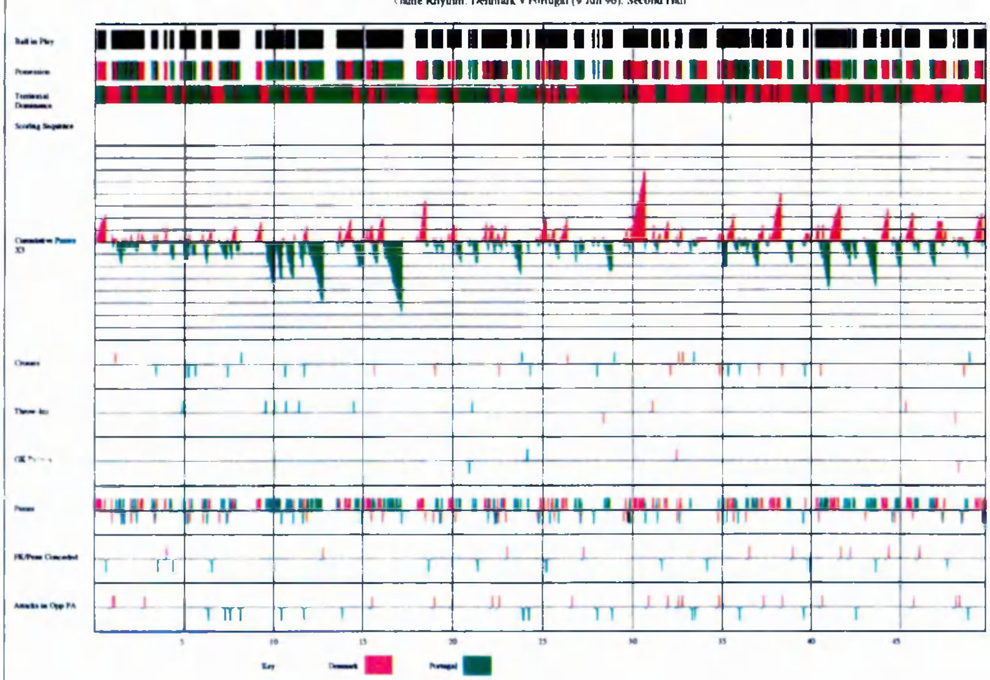
Game Rhythm: England v Ireland (16 Mar 96): Second Half



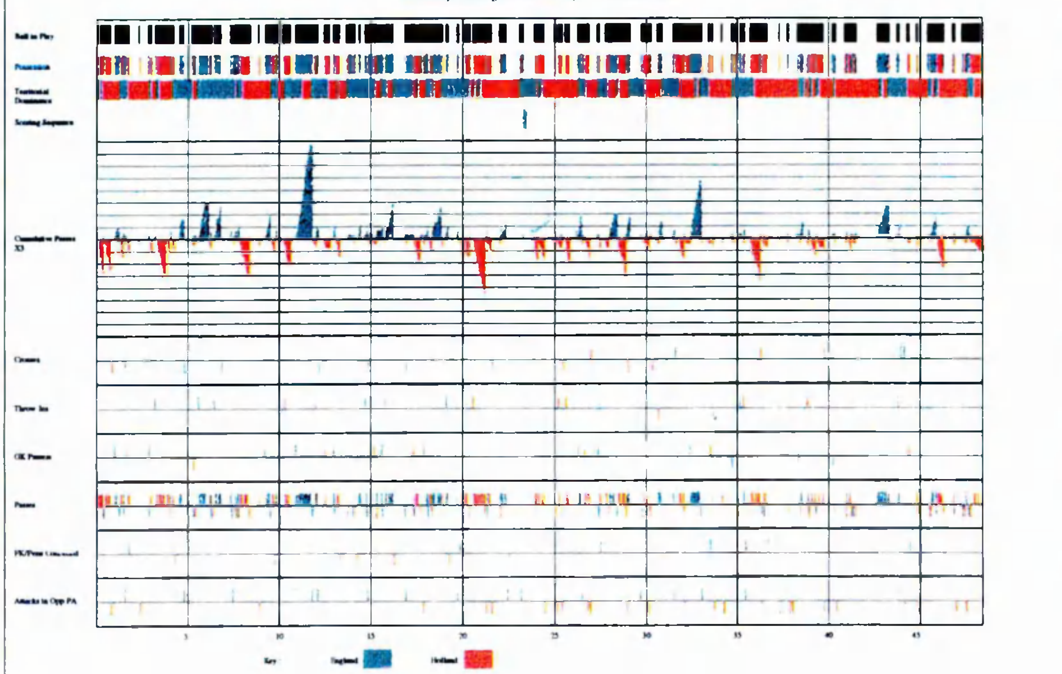
Game Rhythm: Denmark v Portugal (9 Jun 96): First Half



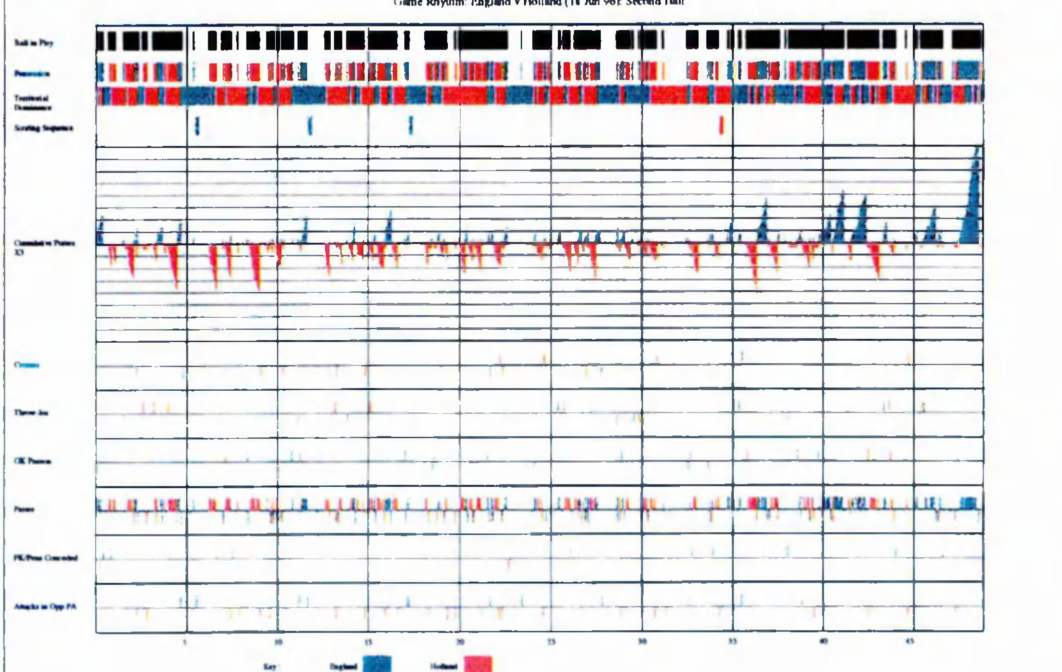
Game Rhythm: Denmark v Portugal (9 Jun 96): Second Half



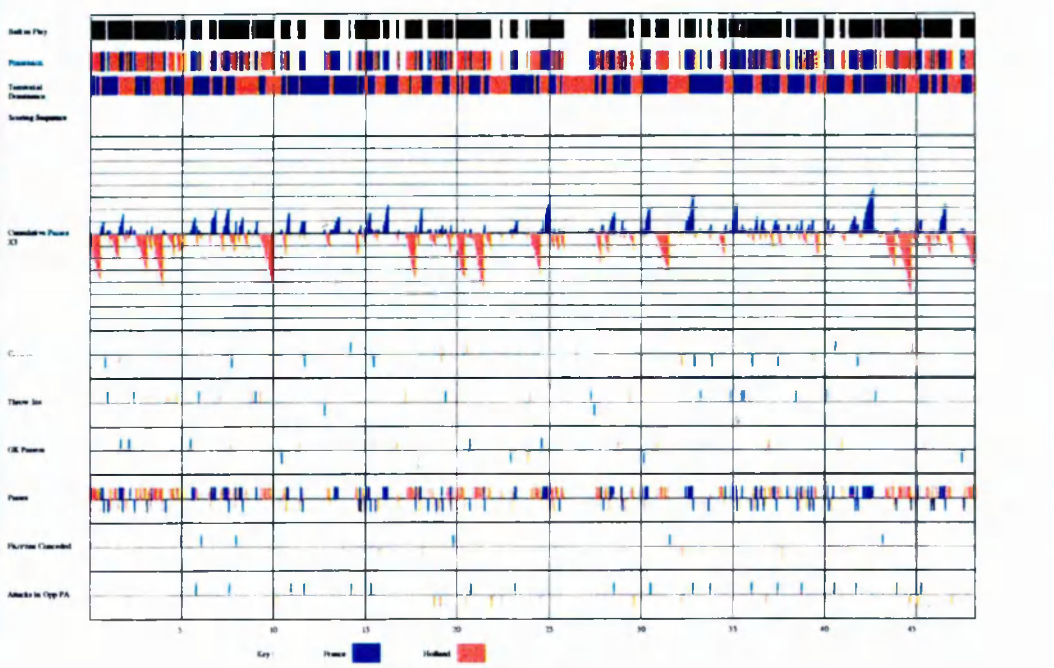
Game Rhythm: England v Holland (18 Jun 96): First Half



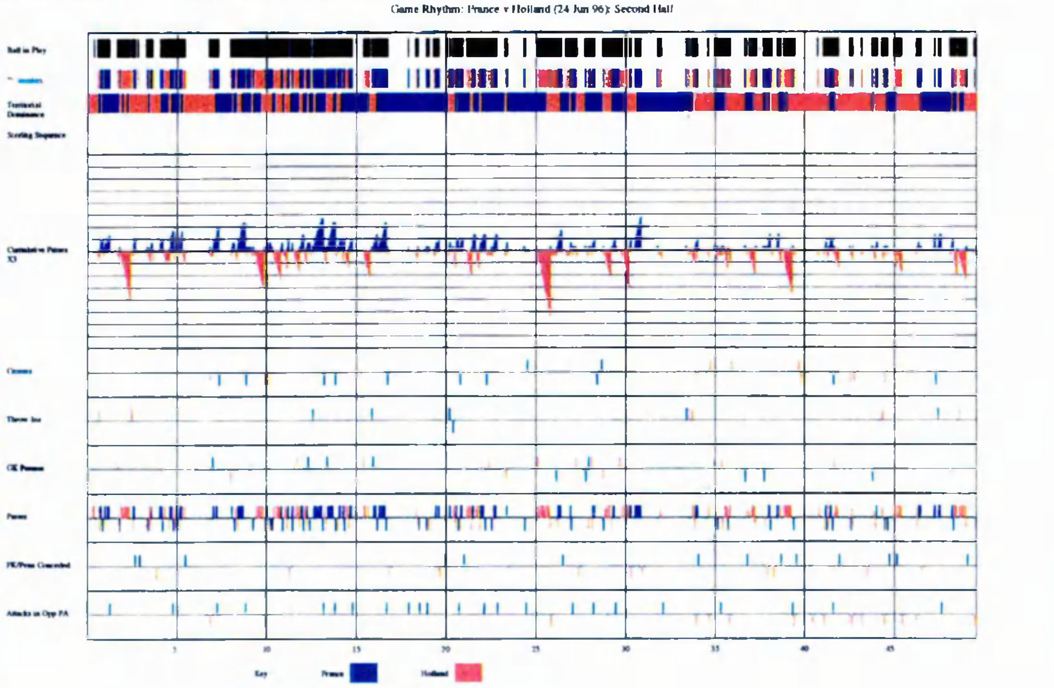
Game Rhythm: England v Holland (18 Jun 96): Second Half



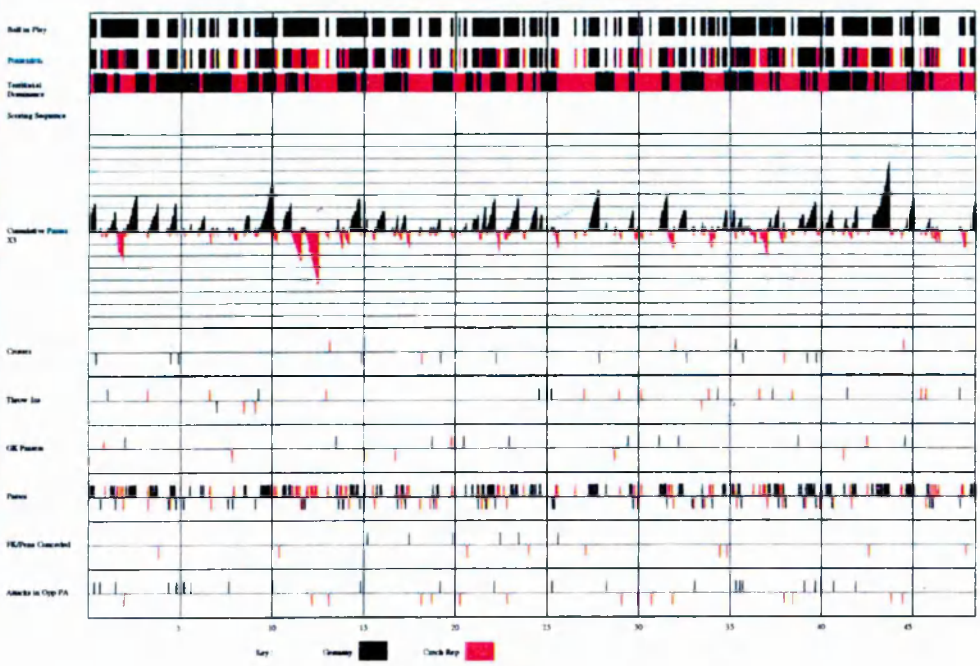
Game Rhythm: France v Holland (24 Jun 96): First Half



Game Rhythm: France v Holland (24 Jun 96): Second Half



Game Rhythm: Germany v Czech Rep (30 Jun 96): First Half



Game Rhythm: Germany v Czech Rep (30 Jun 96): Second Half